

# Biodex Multi-Joint System

Clinical Resource Manual

## 4) Isokinetic Source Book

- Supporting Articles



# ISOKINETIC SOURCE BOOK



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# TUTORIAL FOR BIODEX SYSTEM MULTI-JOINT TESTING AND REHABILITATION SYSTEM

## Introduction to Isokinetics

### Isometric vs. Isotonic vs. Isokinetic

#### Biodex Advantages

#### Definitions and Terminology

## INTRODUCTION TO ISOKINETICS

The BIODEX System 2 is an isolated joint isokinetic system which allows one to measure the amount of strength produced at different velocities. The joints covered are the shoulder, elbow, wrist, hip, knee and ankle.

The easiest way to explain isokinetic loading is by comparing it to isotonic muscle loading. Isotonic muscle loading involves a fixed resistance. Examples of this are sandbags or an NK table. The speed at which the extremity moves is variable. Most isotonic exercise takes place around 50 to 60 degrees of movement per second.

Isokinetic muscle loading consists of fixed speed of movement and resistance that is variable, and most importantly, totally accommodating. Because the resistance is accommodating, it allows for maximal muscle loading throughout the entire range of motion.

Speed is expressed in degrees of movement per second around an axis of rotation. Speed can be adjusted from 0 degrees of movement per second (isometric) to 450 degrees per second. If one moves less than the preselected speed, resistance will immediately be eliminated from the limb.

As stated, isokinetic exercise consists of variable resistance that is totally accommodating. Resistance accommodates to: 1) changes that occur in the musculoskeletal leverage system, 2) blix curve, 3) fatigue, and 4) pain.

Isotonics loads a muscle maximally at the weakest points in the ROM (extreme ends) and is very inefficient loading at mid-range. Isokinetics loads the muscle maximally at every degree throughout the entire ROM.

What happens when a patient fatigues lifting a cuff weight (isotonic muscle loading)? The weight or resistance does not change. Because resistance is fixed, the patient's range of motion decreases as he tires. Isokinetic muscle loading accommodates to fatigue, isotonic muscle loading does not.

As a muscle fatigues with isokinetic loading, it automatically meets less resistance. Even though fatigued, the patient can still work the extremity through the full range of motion from the first repetition to the last.

Isotonic muscle loading does not accommodate to pain. If the patient feels pain when lifting a weight, he will usually drop the weight. With isokinetic loading, if the patient feels pain and lets up, so does the amount of resistance. After the patient bypasses the point in the range that is painful, the resistance will accommodate to the patient's torque output.

## ISOMETRIC vs. ISOTONIC vs. ISOKINETIC CONTRACTION TERMINOLOGY:

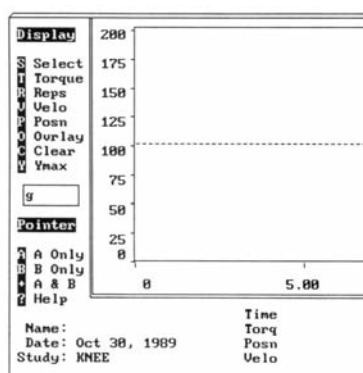
A muscular contraction occurs when the muscle develops tension. Generally during a contraction the fibers shorten, but depending on the type of contraction either a lengthening or shortening can occur. There are two basic contraction types, concentric and eccentric.

### Concentric Contraction:

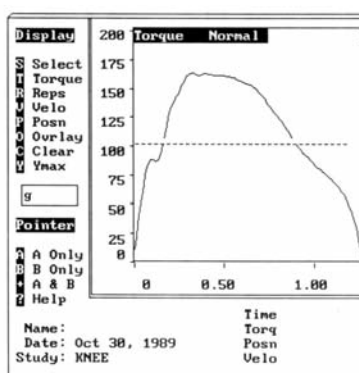
Muscle tension is developed to accelerate a lever arm. As the muscle contracts concentrically, its fibers shorten and the origin and insertion are drawn together. This is often termed positive work.

### Eccentric Contraction:

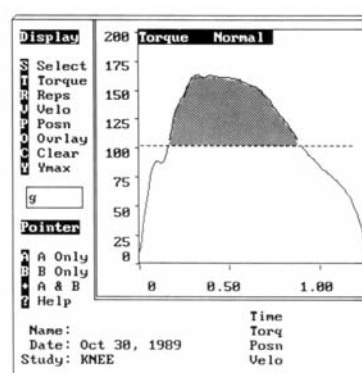
Muscle tension is developed to decelerate a lever arm. As the muscle contracts eccentrically, its fibers lengthen and the origin and



Isotonic muscle loading has a fixed resistance throughout the ROM.



Isokinetic loading has accommodating resistance throughout the ROM.



Shaded area represents muscle potential from isokinetic exercise not obtainable from an isotonic contraction.

insertion are drawn apart. This is often termed negative work. Eccentric loading has been shown to develop up to 400% more tension than concentric loading isotonically.

### **ISOMETRIC**

#### **Contractions:**

In an isometric, or static, contraction, as the muscle develops tension, the fibers shorten, but no movement of the lever arm takes place. Since velocity is held constant at zero, resistance automatically varies to match the force applied.

#### **Advantages:**

1. Involves little or no equipment.
2. Easily taught and performed.
3. Helps retard atrophy.
4. Maintains neural association.
5. May be used with immobilization.
6. May focus on specific points in the range of motion.
7. Used early in rehabilitation without causing joint irritation since there is no joint motion.
8. Assists in decreasing swelling as muscles act as a muscular pump.
9. Can be performed anywhere, anytime.
10. May be made goal oriented with the use of biofeedback.

#### **Disadvantages:**

1. Difficult to determine an objective measurement of effort.
2. Strength gains are fairly specific to the joint angle, with minimal overflow, (plus or minus 10 degrees) to surrounding portions of the range.
3. Little functional carry over.

### **ISOTONIC**

Isotonic exercise utilizes either a constant or pre-selected variable form of resistance. Due to changes in the musculoskeletal leverage system, the muscle tension needed to move the load changes as the joint moves to different positions gaining and losing mechanical advantages.

Therefore, the muscle is only loaded at the joint's weakest point mechanically.

Isotonic exercises are divided into concentric and eccentric muscle loading, described previously.

#### **Equipment:**

There are two essential types of exercise equipment. One is fixed resistance, examples of which include the NK table, dumbbell, and barbell weights. The other form involves preset variable resistance. This attempts to increase resistance at specific angles while going through the range of motion. This is usually accomplished through a custom designed cam. The cam provides greater or lesser tension at certain joint angles according to the shape of the cam. While this form of equipment does allow for variable resistance, it is not accommodating. Also to match each individual's length tension capabilities at every point in the range, a different cam would have to be designed for each person.

#### **Advantages:**

1. Patients may easily see strength increases, and are thus motivated by achievement.
2. May be progressively increased in varying increments to accomplish the overload principle.
3. May be accomplished with a variety of equipment and

techniques.

4. With movement involved, more closely approximates functional activity.
5. Involves a Concentric/Eccentric contraction.
6. Improves muscular endurance.
7. May objectively document.
8. May improve the neurophysiology system.
9. Relatively inexpensive and readily available.
10. Program may be easily regulated.

#### **Disadvantages:**

1. Maximum loading occurs only at the weakest part of the range of motion.
2. Does not accommodate for pain, fatigue, or the musculoskeletal leverage system.
3. Does not develop accuracy at fast functional speeds, and is difficult to exercise at faster, more functional velocities.
4. Fatigue causes a decrease, or compromise, in range of motion.
5. Velocity, work, and power are not controlled or measured and therefore cannot be reproduced.
6. Once weight is moving there is a momentum factor.
7. Maximal eccentrics may cause muscular soreness.

### **ISOKINETIC**

Isokinetic loading involves a fixed speed with variable resistance which accommodates to the muscle's ability to generate force. It is characterized by constant velocity at a pre-selected rate. Resistance varies to match the exact torque/force applied throughout the range of motion.

#### **Advantages:**

1. By controlling the speed of movement, testing and exercise conditions can be reproduced.
2. Accommodates to changes in the musculoskeletal leverage system, muscle fatigue, and pain.
3. Helps develop force, quickness, and time rate of tension development.
4. The muscle group can be loaded to its maximum capability throughout its entire range of motion, making the exercise more efficient.
5. The patient always meets an appropriate amount of resistance, because the resistance is equal to the force applied.
6. Ability to simulate faster, more functional speeds.
7. Allows for velocity spectrum training, to train the muscles neurophysiologically.
8. Inherently safe.
9. Minimal muscle soreness.
10. Validity of equipment.
11. Reliability of testing.
12. Objective permanent record.
13. Improves reciprocal innervation.

#### **Speculative Advantages:**

1. Physiological overflow from faster to slower speeds.
2. Facilitation of normal functional joint arthrokinematics.
3. Decreased joint compressive forces with increasing speeds of exercise.
4. Facilitation of joint lubrication.
5. Objectively able to work submaximally.
6. Assists in diagnosis and prognosis.

**Disadvantages:**

1. Cost of system limits purchase to clinicians only as opposed to the general public.
2. Time consuming when exercising more than one joint.
3. Lack of personnel trained in optimal usage.

**Specific Advantages of Isokinetics:**

1. Safety.
2. Efficiency.
3. Accommodating resistance.
4. Physiological overflow.
5. Velocity spectrum training.
6. Ability to exercise at fast, functional contractile velocities.

**BIODEX ADVANTAGES**

The Biodex System 2 incorporates four modes of exercise: Passive, Eccentric, Isokinetic and Isometric. The Passive and Eccentric modes are also controlled at a constant velocity while giving accommodating resistance, thus, are isokinetic.

**PASSIVE**

1. Allows either concentric or eccentric contractions for the agonist or antagonist muscle groups.
2. Capability to set maximum eccentric torque thresholds for safety of patient.
3. Allows from 1 to 4 second pause for controlled static stretch, or recruitment of muscle fibers isometrically before movement occurs.
4. Allows muscles to warm up before working, continued joint lubrication between work bouts, and buffering of lactic acid between work bouts.
5. Will passively carry limb through pre-selected range if muscle capability is not present.
6. Ability to work through a pre-selected range.
7. Allows for a combination of contraction types to mimic functional activities.

**ECCENTRIC**

1. Allows for more advanced form of exercise training.
2. Minimum and maximum thresholds are preset for specific windows of recruitment.
3. Safety. If torque exerted causes painful arc, or cycle to occur, patient has ability to cancel movement at any instant by halting force production.
4. Ability to preset any selected range.
5. Ability to objectively work submaximally.
6. May work on deceleration of a body part.

**ISOKINETIC**

1. Speeds can be selected from 20 to 450 degrees per second.
2. Agonist/Antagonist speeds can be set independently.
3. Torque capability of 650 foot pounds.
4. Ability to preset any selected range.
5. Ability to objectively work both maximally and submaximally.
6. Ability to set work, rep, or time goals in rehabilitation mode.
7. Objective permanent record post-exercise in rehabilitation mode.

**ISOMETRIC**

1. Ability to evaluate and rehabilitate muscle group at any specific joint angle.
2. Can begin to rehabilitate patients either after injury/surgery, since isometrics involve no joint movement.
3. By using early in rehabilitation, can help retard atrophy, along with assisting in decreasing swelling by muscular pumping action.

**DEFINITION OF PARAMETERS ON THE OUTPUT REPORT****Ratio:**

Relation of the agonist to the antagonist expressed as a percentage.

**Deficit:**

An index of proportionality of the difference between the joints bilaterally. Allows for charting progress of rehabilitation.

**Torque:**

A function of force and distance from the axis of rotation as measured by the Biodex dynamometer.

**Work:**

Force multiplied by distance produced throughout the entire range of motion. It is the area under the curve.

**Power:**

Work divided by the time taken to perform the work. This can provide a true measure of work rate intensity. Average power can be used to find an individual's most efficient exercise speed.

**Reciprocal Innervation Time:**

Measures time from completion of an agonistic contraction to the start of an antagonistic contraction.

**Force Decay Rate:**

The downslope at the torque curve, from the point of maximal torque production to where torque production ceases for that movement.

**Peak Torque:**

The highest value of torque developed throughout the range of motion.

**Time to Peak Torque:**

A measure of time from the start of the muscular contraction to the point of highest torque development. An indicator of the functional ability to produce torque quickly.

**Angle of Peak Torque:**

Point in range of motion where peak torque is achieved. A task specific test of the functional ability of a joint. Peak Torques will usually occur at nearly the same position for similar movements and speeds.

**Torque @ 30.0 Degrees:**

Displays the torque produced for each direction at the pre-selected position. The position of 30 degrees is a critical point in knee stabilization, especially since the knee flexes to about 30 degrees during normal ambulation.

**Torque @ 0.20 Second:**

Displays the Time Rate of Tension Development. The time of 0.20 seconds is pre-selected because it has been documented that upon heelstrike it takes the leg extensors 0.20 seconds to develop enough force to support the body in normal ambulation. Possibly one of the best indicators of the indicators of a rehabilitated joint.

**Peak Torque to Body Weight:**

A ratio displayed as a percentage of the maximum torque production to the subject's body weight.

**Max Rep Work:**

The maximum work, force times distance, produced in a single repetition. A better indicator of the functional ability of a joint than Peak Torque, since the muscle must maintain force throughout the range of motion as opposed to force in one instant.

**Work to Body Weight:**

A ratio displayed as a percentage of the maximum rep work to the subject's body weight.

**Total Work:**

The sum work for every repetition performed in the bout.

**Work First Third, Work Last Third:**

The entire work bout is divided into thirds. This is the total work of the first one-third of the reps and last one-third of the reps.

**Work Fatigue:**

The ratio of the difference, expressed as a percentage, between the work in the first third to work in the last third of the test bout.

**Average Power:**

The total work divided by the time it takes to perform the work. Power is used to measure muscular efficiency.

**Maximum ROM:**

The greatest range the exercised joint achieved during a test bout.

**Anatomical ROM:**

The ROM recorded in degrees anatomically specific to the joint being tested.

**Maximum GET:**

In order to eliminate Gravity's Effect on Torque the limb weight is determined. The limb weight is then added to torque values when working against gravity and subtracted from torque values when working with gravity.

**DEFINITION OF PARAMETERS OF AN ISOKINETIC OUTPUT REPORT****Coefficient of Variance:**

The ratio between the Standard Deviation and the mean value for a statistical population expressed as a percentage used to objectively determine the reproducibility of test data.

**Agonist/Antagonist Ratio:**

A ratio between the agonist and antagonist muscle groups tested.

**DEFINITION OF PARAMETERS OF AN ISOMETRIC OUTPUT REPORT****Maximum Average Torque:**

The greatest average torque produced for a repetition within a set.

**Mean Average Torque:**

The mean of the average torques within a set.

**Maximum Average Torque/Body Weight:**

A ratio displayed as a percentage of the Max. Avg. Torque to the subject's body weight.

**Work:**

Work is classically defined as force multiplied by distance. However, in the isometric mode, the distance component does not exist due to the nature of the exercise. The measurement of work in the isometric reports, (which may be considered an impulse), is viewed as a "physiological" opposed to a mechanical parameter. Isometric work is therefore calculated as force multiplied by time, or more specifically the duration of the contraction.

**DEFINITION OF PARAMETERS OF A LIFT REPORT****Note:**

The measurement parameters in the Isometric lift reports are referred to as force rather than torque due to the linearity, opposed to rotational, component of the exercise. Therefore, the measurement is recorded as lb-sec.

**Peak Force:**

The highest value of force developed throughout the duration of the contraction.

**Maximum Average Force:**

The greatest average force produced for a repetition within a set.

**Average Force Deviation:**

Summation of the absolute value of the Mean Average Force for the set minus the average force for each repetition. This number is then divided by the number of repetitions performed.

**Average Work Deviation:**

Summation of the absolute value of the average work for the set minus the work for each repetition. This number is then divided by the number of repetitions performed.

number of reps

$$\sum_{i=1} [MAF_{set} - AF_i] / \text{number of reps}$$

i=1

**Joint Performance Index:**

A percentage of the maximum torque which a particular joint may experience before being at risk of injury. The software calculates the torque applied to each joint for a particular test position.

number of reps

$$\sum_{i=1} [AW_{set} - W_i] / \text{number of reps}$$

i=1



# ISOKINETIC TESTING: GOALS, STANDARDS AND KNEE TEST INTERPRETATION

Kevin E. Wilk, PT, EMT  
Clinical Director  
Healthsouth Sports Medicine & Rehabilitation Center  
Director of Rehabilitation Research  
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Birmingham, Alabama

The clinician's ultimate goal is to return the patient to an acceptable level of function. To achieve this goal, a carefully designed rehabilitation program must be developed based on healing restraints and on each individual's unique anatomic, neurologic and psychologic characteristics. These characteristics should be evaluated both objectively and subjectively, and can be used to guide the patient's progress through a rehabilitation program.

Subjective evaluation includes attention to patient symptoms, such as pain, stiffness and changes in function. Since the evaluation is based primarily on the patient's perception of his symptoms, it may be unreliable at times and inconsistent from patient to patient and from visit to visit. Nonetheless, when patients complain of an increase in pain and stiffness, their exercise programs may be reduced to a less strenuous level.

An objective approach, however, to patient rehabilitation uses "criteria-based protocols" developed from the results of careful system evaluations. Criteria considered include clinical data from anthropometric and goniometric measurements, palpation, manual muscle testing (MMT), functional performance and objective tests - isokinetic, proprioceptive and knee arthrometry. Through the use of such criteria, rehabilitation protocols can be developed that allow quantification and documentation progress. This makes it easier to evaluate the patient's status and to communicate with other clinicians, third-party insurers and the patient himself. It also allows the clinician the opportunity to establish short-term and long-term goals based on objective reproducible data.

Isokinetic muscle evaluation and exercise make it possible to keep a limb in motion at a constant, predetermined velocity while applying accommodating resistance throughout the range of motion (ROM). Thus, increased muscular output produces increased resistance rather than increased acceleration (speed) - momentum and inertia - which is what occurs in gravity-loaded (isotonic) systems of exercise.

Although isokinetic technology has been available for over 20 years, recent technologic advances, such as the ability to assess the muscle at faster speeds, make it possible to evaluate eccentric-contraction torque and quantify more aspects of muscular performance. Those advances also permit generation of other data, such as average power, total work and endurance. This has dramatically increased the number of clinicians interested in using isokinetics.

An American Academy of Orthopedic Surgeons (AAOS) task force on quantifying disability developed a set of guidelines that asks the following questions regarding isokinetic testing:

- Does the system allow for proper application to the joint being tested?
- Is the equipment safe?
- Is the system valid and reliable?
- Is there educational support from the manufacturer?

The BIODEX system fulfills all the criteria established by the AAOS. It allows various modes of exercise such as isokinetic concentric and eccentric, as well as isometric or passive motion. In the passive mode, continuous passive motion (CPM), concentric and eccentric exercise can be performed. The isokinetic mode permits concentric/concentric movement and the eccentric mode permits eccentric/eccentric movement. In the isometric mode, evaluation and testing of static strength is possible for any muscle group at any specific joint angle.

One of the most exciting areas of isokinetic testing is the ability to evaluate muscular performance objectively and to establish specific criteria prior to a return to activities. The proper interpretation of test data is the primary subject of this article.

## KEY CONCEPTS

There are numerous problems inherent in MMT. The technique is inconsistent in application and grading. It is a relatively subjective test and the inter-rater reliability is poor. In addition, it is a static test and gives no information regarding muscular performance. Therefore, the clinician requires a more sophisticated test than MMT. At the present time, isokinetics gives the clinician a valid, objective, reliable test that is dynamic and safe.

An objective reproducible test system is imperative to the clinician for several other reasons: first, to document disability for medical and legal documents, and second, to ensure objectivity regarding patient progression.

## STUDIES

To prove validity and reliability of the Biodex system, Wilk et al tested 24 subjects for knee flexion and extension at 60, 180, 360 and 450 degrees per second. Each subject was tested twice with 2 days rest between tests. Analysis of data on multiple trials revealed Pearson correlation coefficients that indicated that Biodex is a reliable test device. Several other investigators have all reported similar results.

## STANDARDIZED TEST PROTOCOLS

A consistent, standardized testing protocol is designed to improve reproducibility from test to test and from subject to subject. A standardized testing routine improves the clinician's control of several variables that influence tests. Wilk has described a standardized testing protocol for the knee and shoulder.



An isokinetic testing protocol should include standardization of the following variables:

- patient education
- testing of uninvolved side first
- alignment of axis of rotation
- warm-ups
- patient stabilization
- verbal commands
- visual feedback
- test position
- system calibration
- angular velocity selection
- system stabilization
- skill, training of tester
- gravity compensation
- rest intervals
- test repetitions

For this discussion, test protocols and angular velocity deserve particular mention.

### TEST PROTOCOLS

The Biodex system offers several test protocols: isometric, isokinetic concentric, isokinetic eccentric, isokinetic concentric/eccentric, isokinetic eccentric/concentric and endurance testing. To determine the best type of test for each situation, avoid thinking of testing as a means of measuring strength. Instead, consider what type of test will help identify problems of overall muscle performance during the patient's functional activities.

### ANGULAR VELOCITY

The goal of rehabilitation is to return patients to functional activity. Several estimates of functional speeds have been identified for the knee:

- walking - 233 degrees per second
- running - 1,200 degrees per second
- punting - 2,865 degrees per second

Some other estimates of functional speeds are:

- the shoulder during throwing —  $\geq 7,000$  degrees per second
- the elbow during throwing — 1,825 degrees per second
- the ankle during running — 540 degrees per second

Reviewing these values, therefore, would indicate that even to estimate functional ability, patients need to be tested and trained at fast speeds. This is referred to as "functional training for dynamic stabilization."

These speeds cannot be approached with isotonic equipment. Pipes showed that knee extension on progressive resistive equipment reaches a maximum of 60 to 90 degrees per second. Much faster speeds are obtained using isokinetics, surgical tubing or even during pool-running. High-load, low-speed training only produces low-speed gains. To return patients to high-speed activities, they need high-speed training as early as tolerated.

Testing at higher functional speeds has been shown to limit tibial translation. In one study, Wilk looked at the effects of pad placement during isokinetic exercise on ACL-deficient knees. At every speed, distal pad placement caused greater tibial translation than proximal pad placement. Also, 60 degrees per second caused

greater tibial translation in the ACL-deficient knee than did 180 or 300 degrees per second. The greatest amount of anterior translation occurred at a mean of about 28 degrees of knee flexion.

### SUBJECTIVE ASSESSMENT

Finally, when testing patients, it is important to listen to their reactions. If the patient experiences popping, cracking or discomfort, the joint should be palpated to identify the angle at which the problem occurs. Then, the patient's symptoms should be compared with his torque curves and a subjective grade assigned - eg, grade 2 crepitus at 90 degrees of flexion. We grade crepitus by assigning it a value between 0 (none) and 4 (severe).

### BASIC TEST INTERPRETATION

From the information gathered during Biodex testing, several important values can be obtained:

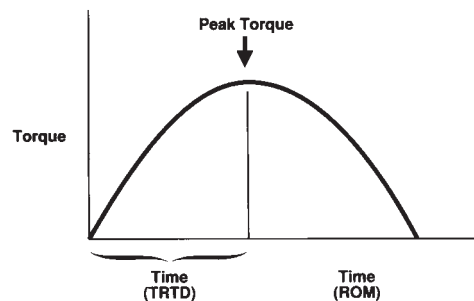
- torque parameters
- acceleration parameters
- force decay rate
- ROM
- muscular performance parameters

Proper interpretation of these values can aid significantly in the identification of joint and muscular pathologies and in the development of a comprehensive rehabilitation program.

### TORQUE

Peak torque (PT) is the highest point on a patient's extension/flexion curve, regardless of where in the ROM it occurs. In contrast, mean peak torque is the average of the peak torque values obtained during a series of repetitions. Mean peak torque may be considered a better estimate of overall function than peak torque, since function is dependent on repetition of movement.

*Fig 1. Bell-shaped torque curve — x-axis represents time,*



*y-axis represents force — showing both peak torque, the highest point on a patient's extension/flexion curve.*

### ACCELERATION PARAMETERS

Time rate to torque development (TRTD) indicates how quickly torque develops during a muscle contraction. In normal individuals, PT occurs during the beginning one-third of the upward slope of the torque curve. If the upward slope of the curve is prolonged, with maximum torque occurring in the middle or final third of the curve, it indicates difficulty in generating torque at the onset of the muscle contraction. In such cases, due to decreased acceleration ability, the patient may not be ready to return to functional activities.

TRTD may be examined in relation to several parameters:

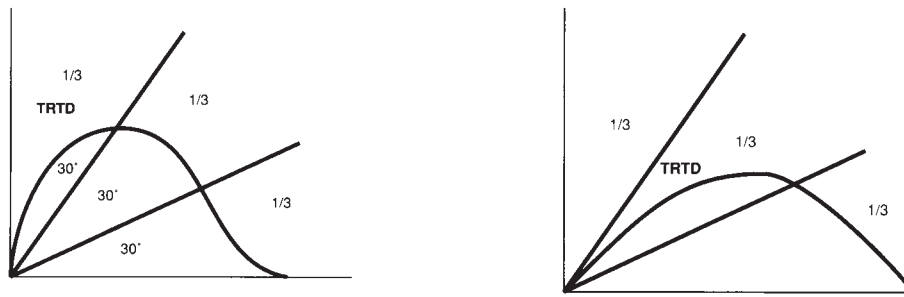


Fig 2. "Normal" curve (left) shows PT occurring during beginning one-third of upward slope. Prolonged TRTD (right) indicates difficulty generating muscle contraction.

- the PT - measured from the start of a muscle contraction to the highest point on the torque curve
- a predetermined torque value - the time it takes an extremity to produce a specific torque value is calculated
- a predetermined time - the torque produced at a specific time is measured
- a specific angle - the torque produced at a specific angle is evaluated

Depending upon the pathology, different parameters may be useful. For example, Wilk showed that by 0.2 seconds the knee should be able to achieve 80% to 90% of its peak torque. The angle of the knee at heel strike is 0 to 5 degrees and at mid-stance the knee angle is 20 degrees. At this point, a significant amount of torque is needed for dynamic stability of the knee during ambulation. Therefore, for the knee, TRTD at 20 degrees has become a popular parameter to collect during an isokinetic knee test.

### FORCE DECAY RATE

Force decay rate (FDR) is the term used to describe the downslope of a torque curve. It is the section of the curve showing where force - torque - decreases. In most cases the downslope of a torque curve should be either straight or convex. If the downslope is concave, it may indicate that the patient has difficulty producing force as he or she reaches terminal extension; it is, therefore, indicative of some pathology. In patients with a deficient anterior Cruciate ligament (ACL), concavity tends to occur between 20 degrees and 30 degrees.

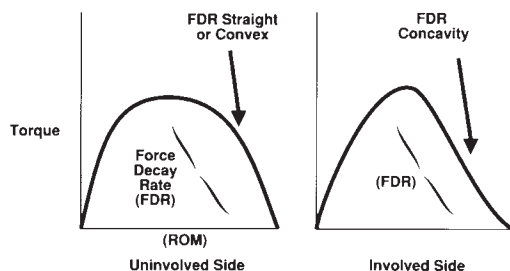


Fig 3. "Normal" FDR pattern (left) is straight or convex. Concave downslope (right) indicates difficulty producing force.

### RANGE OF MOTION

ROM curves used as overlays of torque curves indicate, in a range, the precise points where deficiencies occur during joint testing. In back testing, ROM is also used as an indicator of test validity and reliability.

### MUSCULAR PERFORMANCE

Besides the basic parameters described above, examination of several additional parameters is useful for interpreting the results of isokinetic reports. These parameters measure muscular performance during isokinetic exercise or testing.

Total work (TW) is defined as force multiplied by distance. This value is represented by the "area under the curve" along the x-axis. This parameter is speed- and motion-dependent. It is common to see bilateral equality for PT and ROM. However, a patient can demonstrate a TW deficit. A valuable test parameter is TW:body-weight ratio.

Average power is defined as TW divided by time - the time it takes to perform the work. This parameter is expressed in terms of watts. We evaluate this test parameter in terms of age power divided by body weight.

Reciprocal innervation time (RIT) indicates the amount of time from the termination of an agonist contraction to the onset of the antagonist contraction. For example, it indicates how quickly an individual can begin a hamstring contraction following a quadriceps contraction during a knee test. The portion of a torque curve between the end of extension and beginning of flexion appears as a "U" rather than a "V" if there is a delay in RIT.

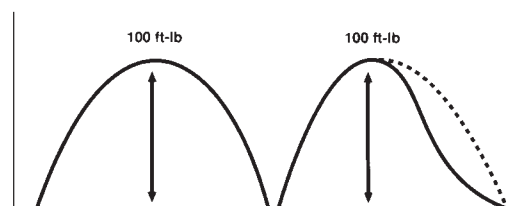


Fig 4. Work "area under the curve" is less for curve on right, even though peak torque remains the same as curve on left.

## OTHER WORK PARAMETERS

Several other work parameters also give indications of performance and endurance:

- work:body-weight ratio
- work produced during the first third of the curve
- work produced during the last third of the curve
- work fatigue percentage

This last value, work fatigue percentage, is computed by the Biodex. It compares the first third of work in a series of repetitions to the last third of work in a series of repetitions and then generates a percentage that helps evaluate endurance.

## CORRELATION OF TORQUE CURVES WITH PATHOLOGIES

Careful observation of Biodex torque curves can assist the clinician in identifying specific pathologies. To illustrate this process, some specific curve patterns for various knee pathologies follow. A torque curve can be divided into three regions:

- acceleration (engagement)
- torque obtainment
- force decay rate

A normal extension/flexion curve is illustrate in Fig. 2 (left). Note the smooth shape of the curve with peak torque obtained in the mid-point of the ROM. Deviations from this pattern indicate particular problems that can be related to a variety of pathologies.

## PATELLOFEMORAL CHONDROSIS

Patellofemoral problems\* tend to be easy to identify because they deviate significantly from normal torque curves. In the torque obtainment phase, there tends to be a dipping that coincides with the patient's experience of discomfort. Generally, there is a decreased production of torque, a plateau during mid-range motion, and possible irregularity throughout the quadriceps portion of the curve are common (Fig 5). From a pathomechanical perspective, this pattern results secondary to pain, which shuts down the muscular contraction, and is a classic example of pain inhibition. Several investigators have documented this type of torque curve.

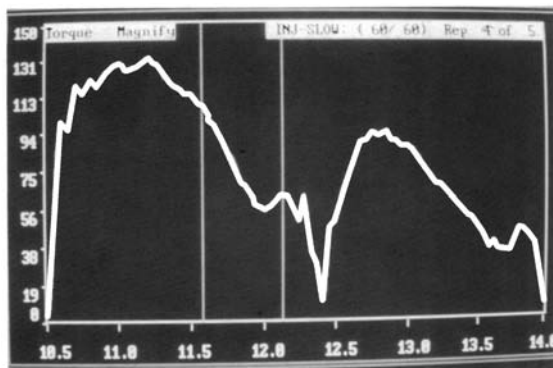


Fig 5. Patellofemoral chondrosis — pain inhibition, rapid FDR with inability to maintain force near terminal extension

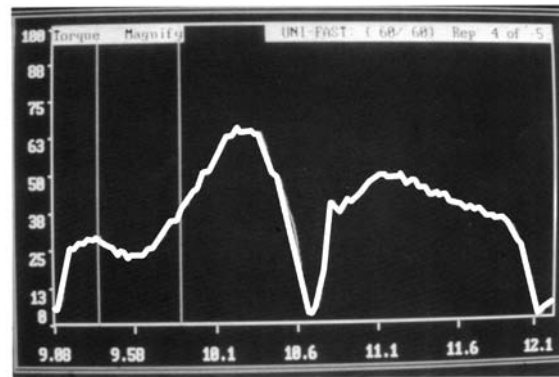


Fig 6. Plica syndrome. During extension double-humped curve with second higher than first and rapid FDR.

## PLICA SYNDROME

Patients with plica syndrome produce a double-humped curve during the quadriceps component. The second hump is higher than the first and has a rapid FDR. This pattern appears in response to compression of the plica which, during flexion, stretches over the medial femoral condyle. As the patient extends his or her knee, the plica becomes lax at 40 to 0 degrees and, thus, the pain is relieved and torque is generated.

## PATELLA SUBLUXATION

A double-humped curve also occurs during the quadriceps component in cases of patella subluxation (Fig 7). However, in contrast to plica syndrome, where the second hump appears larger than the first, in patella subluxation the first hump appears larger than the second.

In this case, the patella rests comfortably in the trochlear groove at 90 degrees flexion, and there is maximum congruency. As the leg extends, the patella rides out of the trochlear groove at approximately 20 degrees to 30 degrees ROM, to muscular imbalance, the joint's geometry and ligamentous restraints. In individuals with patella alta, a high-riding patella, this phenomenon is often observed.

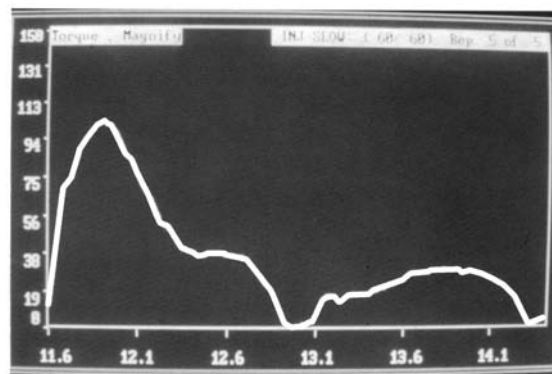


Fig 7. Patella subluxation. During extension, double-humped curve with first hump higher than second.

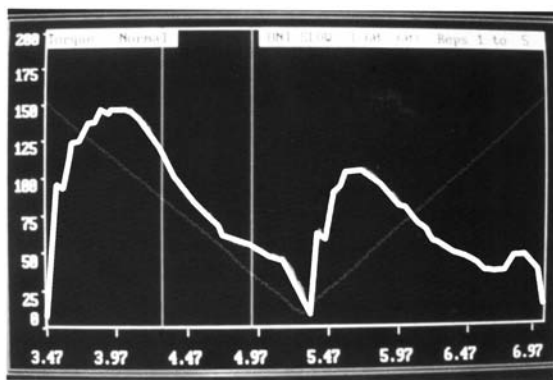


Fig 8. ACL deficiency. Rapidly decreasing FDR at extreme od ROM or plateau with dip in quadriceps strength mid-ROM.

#### ACL DEFICIENCY\*

Torque curves of ACL-deficient knees generally show one of two patterns, originally described by Malone and Mangine. In more severely compromised knees, a plateau in quadriceps strength appears as a dip, mid-ROM, at about 30 to 45 degrees and causes a pivot shift phenomenon. In less severely compromised knees, the FDR decreases rapidly, with concavity, as patients reach the extreme of their ROM (Fig 8).

Since the greatest amount of anterior tibial translation occurs at 20 to 30 degrees ROM, knee extension during this range appears as a deformity in the normal torque curve.

#### CURVE ANALYSIS SUMMARY

In general, several factors should be considered when performing curve analysis:

- The four knee curves discussed are relatively easy to identify.
- A goal of the clinician is to learn to identify subtle curve deformities to avoid exacerbating the existing pathology.
- An increased FDR, represented by concavity in the FDR, indicates a loss of torque in the end range.
- Decreased mid-range torque values indicate patellofemoral pathology.
- Disregard torque for the first 12 degrees ROM.

In addition, clinicians should always remember that a clinical diagnosis cannot be made solely from examination of a torque curve. These patterns should always be correlated with clinical findings.

#### ANALYZING SUMMARY REPORTS

The previous sections of this article reviewed the raw data generated by the Biodex system. This suggest will suggest a logical method of examining the data so that it can be used as a guide to rehabilitation.

#### DATA ANALYSIS

All Biodex data can be evaluated in terms of the raw numbers generated - PT, TW and PT at a specific angle - referred to as "absolute data analysis". Therefore, at 180 degrees per second a patient generates 100 ft-lb during extension (quadriceps) and 69 ft-lb during flexion (hamstrings). The hamstrings strength is 69% of the quadriceps strength.

"Relative data analysis", another method of interpreting data, entails the examination of one absolute value in relation to another value, such as body weight. For example, if a patient weighs 200 lbs, peak torque of the quadriceps is divided by body weight, and the result is only 50%.

Functional relative data analysis (FRDA) compares an absolute value in relation to body weight and yet another value, usually time. As mentioned previously, average power is determined by dividing total work by time. From this value, a functional analysis can be made by dividing the average power by body weight, yielding a value of watts per pound. Finally, to obtain a functional test score, the value is multiplied by 100.

#### BILATERAL COMPARISONS

We have all come to depend on bilateral comparisons as the "Old Faithful" of data analysis. It is quick and easy: Bilateral differences greater than 10% are generally considered significant.

Unfortunately, in the presence of a deficit in the contralateral limb - used for a standard - this method of analysis is inaccurate. For example, a gait asymmetry or other underlying pathology, such as patellofemoral chondrosis, will affect the results of a knee test. Therefore, bilateral comparison is, in many cases, a poor method of evaluating joint systems.

#### UNILATERAL MUSCLE RATIO

Another way of evaluating the integrity of a joint is by comparing the ratio of the agonist to the antagonist muscles. Changes in this ratio indicate weakness and are most easily identified during velocity spectrum training. Expected ratios for the normal knee are:

- 60 degrees per second - 60% to 69%
- 180 degrees per second - 70% to 79%
- 300 degrees per second - 80% to 95%
- 450 degrees per second - 95% to 100%

In the ACL-deficient knee, these ratios are frequently 10% higher; in the PCL-deficient knee, they are 10% lower.

#### TORQUE TO BODY WEIGHT

As mentioned during the earlier discussion of data analysis, the torque:body-weight ratio is a good indicator of general joint integrity. When followed by a careful analysis of patient's torque curve, it provides a good deal of information.

Analysis of our patient base has provided the following set of normative data on torque:body-weight ratios specific to the Biodex. In males the data is:

- 60 degrees per second - 110% to 115%
- 180 degrees per second - 65% to 75%
- 300 degrees per second - 45% to 55%
- 450 degrees per second - 35% to 40%

In females the expected torque:body-weight ratios are:

- 60 degrees per second - 85% to 95%
- 180 degrees per second - 55% to 65%
- 300 degrees per second - 35% to 45%
- 450 degrees per second - 25% to 30%

All ratios are based on weight established on a standard scale, not lean body weight.

## THE BOTTOM LINE

The guidelines described in this article are just that - guidelines. If there is any doubt about the validity of an isokinetic test, it should be immediately correlated to the findings on clinical examination and to the patient's ability to reproduce the established test.

The criteria examined on every test should be specific, and the method of evaluation should not vary. Finally, always remember that isokinetic testing is a means of achieving objectivity. The evaluation of muscular and neuromuscular information must always be considered part of a whole - part of the complete evaluation and rehabilitation program.

In summary, there are ten factors that make up the isokinetic bottom line for a knee test:

- peak torque:body-weight ratio
- total work:body-weight ratio
- unilateral hamstring:quadriceps ratio
- torque curve analysis
- bilateral mean peak torque
- bilateral total work
- bilateral average power
- average power:body-weight ratio
- time rate to torque development (torque at 0.2 seconds)
- endurance

Using these factors as basic guides to the interpretation of isokinetic test data will help make isokinetic testing more meaningful and useful. This criteria must be evaluated before a patient an advanced running or sport activity. We have established similar criteria for the throwing shoulder.

In closing, there are four guidelines to remember when interpreting an isokinetic test:

- Correlate your findings to your clinical exam.
- Use specific pre-established criteria for your interpretation.
- Be sure your test is valid and reproducible. If it is not, do not use it. Repeat the test.
- Remember that the isokinetic test is not your only test. This test documents only objective muscular performance. For knee laxity, perform a knee arthrometer test; for functional status, perform a functional test. Other tests, when appropriate, should be part of your regular armamentarium.

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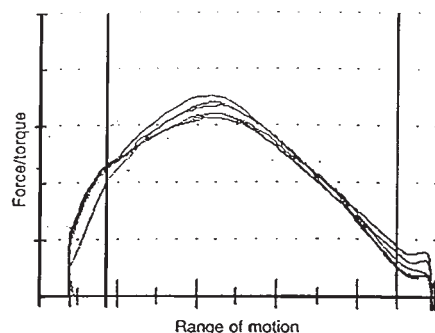


# ISOKINETIC ASSESSMENT

David H. Perrin, PhD, ATC

Isokinetic resistance has several advantages over other exercise modalities. One advantage is that a muscle group may be exercised to its maximum potential throughout a joint's entire range of motion. For example, at the midrange of joint motion (where a muscle is at its optimum length-tension relationship for the binding of actin and myosin and has its greatest mechanical advantage) the isokinetic dynamometer will maintain its preset velocity, and thus more force will be produced. Conversely, at the extremes of joint motion (where a muscle is at a physiological and mechanical disadvantage) the dynamometer will still maintain its preset velocity, but less force will be produced. Because there is no fixed resistance to move through the weakest point in a given arc of motion (as with isotonic exercise), isokinetic exercise facilitates a maximum voluntary force to be produced through the entire range of motion. Figure 1 illustrates the relationship between a joint's range of motion and production of isokinetic force. Figures 2 and 3 compare the force output and percentage of muscle capacity used during isotonic and isokinetic exercise, respectively.

Isokinetic resistance may also provide a safer alternative to other exercise modalities during the process of rehabilitation. Isokinetic exercise is inherently safer than isotonic because the dynamometer's resistance mechanism essentially disengages when pain or discomfort is experienced by the patient. An isokinetic apparatus may also be adapted to the particular rehabilitation challenge at hand. For example, exercise may be submaximal and easily set through pain-free ranges within the total available range of joint motion, and exercise velocities may be selected that have the least potential for joint insult.



*Figure 1. Force output at the skeletal lever during isokinetic exercise. At the extremes of range the muscle has its least mechanical advantage and resistance is least. Toward midrange, where the mechanical advantage is greatest, the resistance increases proportionately.*

Adapted from "The Isokinetic Concept of Exercise" by H.J. Hislop and J.J. Perrine, 1967, *Physical Therapy*, 47, p.116. Copyright 1967 by the American Physical Therapy Association. Adapted with the permission of the American Physical Therapy Association.

Isokinetic exercise may be used to quantify a muscle group's ability to generate torque or force, and it is also useful as an exercise modality in the restoration of a muscle group's preinjury level of strength.

Thousands of abstracts and articles dealing with various aspects of isokinetic exercise have appeared in the scientific literature over the past 25 years. Thistle et al. (1967) were indeed prophetic when they stated, "Accommodating resistance exercise with its faculty for accommodating true muscle force capacity and permitting natural muscle torque curves, promises a new and fruitful approach to muscle exercise and analysis; and the isokinetic device offers many new and exciting applications in the study and understanding of kinesiology" (p.282).

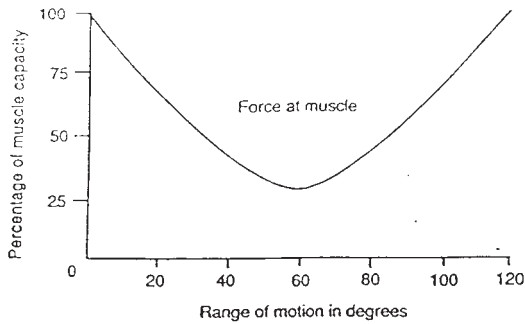


Figure 2. In isotonic exercise, resistance to the muscle varies because of the modifying effects of the lever system. Resistance has its greatest mechanical advantage on the muscle at the extremes of range and consequently the load is greatest at these points. Closer to midrange the lever is most efficient and therefore the load on the muscle is proportionately less. Demands placed on the muscle are maximum only at the extremes of the range.

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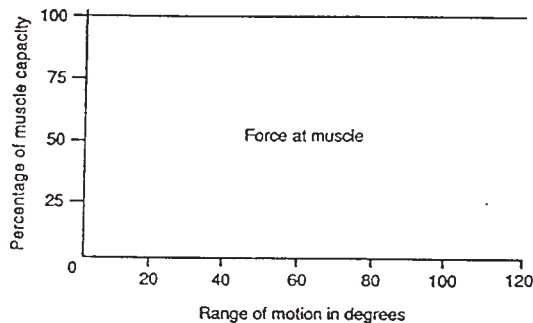


Figure 3. During isokinetic exercise the resistance accommodates the external force at the skeletal lever so that the muscle maintains maximum output throughout the full range of motion.

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## COMPARISON OF ISOMETRIC, ISOTONIC AND ISOKINETIC EXERCISE

### Isometric

#### Advantages

- Useful when joint motion is contraindicated
- Requires minimal or no equipment

#### Disadvantages

- Strength increases specific to exercised joint position
- Absence of feedback from objective increases in strength

### Isotonic

#### Advantages

- Includes a natural component of concentric and eccentric resistance
- Positive reinforcement from progressive increases in resistance
- Permits exercise of multiple joints simultaneously
- Is easily performed from weight-bearing closed-kinetic-chain positions

#### Disadvantages

- Amount of resistance limited to weakest point in range of motion
- Inability to quantify torque, work and power
- Stronger muscles may compensate for weaker muscle groups during closed-kinetic-chain exercise

### Isokinetic

#### Advantages

- Permits isolation of weak muscle groups
- Accommodating resistance provides maximal resistance throughout the exercised range of motion
- Accommodating resistance provides inherent safety mechanism
- Permits quantification of torque, work and power

#### Disadvantages

- Reliable assessment is limited to isolated muscle groups through cardinal planes of motion
- Exercise occurs primarily from non-weight-bearing open-kinetic-chain positions



# SPECIFIC ADAPTATIONS TO ISOKINETIC EXERCISE

Kent E. Timm, PhD, PT, ATC

As a medium for exercise and rehabilitation, isokinetic activity can induce a variety of changes in the different physiological systems of the human body. Changes can occur as the result of prolonged isokinetic activity and may represent a desired direct rehabilitation effect or an indirect modification of existing systemic processes. All changes stem from the principle of specific adaptation to imposed demand (SAID) and reflect the body's response to the conditions associated with isokinetic training. Specific adaptations are known to occur in several areas as the result of spinal isokinetic exercise: the cardiovascular system, connective tissue, muscle tissue, the neurological system and bone. While such changes may be exclusively attributed to the isokinetic mode of exercise, most reflect the body's response to activity which involves some type of external load that is moved in a format of progressive resistance. In addition to systemic changes, spinal isokinetic activity also influences the physiology of the intervertebral disk; this is an important concept which relates the potentials of isokinetic dynamometry to the treatment of patients with disk involvement.

## CARDIOVASCULAR ADAPTATIONS

Isokinetic exercise influences the cardiovascular system by inducing changes in the left ventricle of the heart. The cardiac muscle of the left ventricular wall hypertrophies to increase the potential filling volume of the ventricle during the diastolic phase of the cardiac pumping cycle (3,4). This enhancement of diastolic function leads to an increase in the stroke volume of blood that is pumped from the left ventricle during the systolic phase of the cardiac cycle (3,4). The effect also leads to a net increase in a subject's resting heart rate. The overall influence requires a minimum of eight weeks of isokinetic training and the effect parallels the changes that may be induced within the heart through aerobic and progressive resistance exercise.

## CONNECTIVE TISSUE ADAPTATIONS

Isokinetic exercise enhances the process of collagen synthesis in cells within the region of a connective tissue injury. The effect is largely based upon a facilitation of protein synthesis at the cellular level (2,5). Once new collagen fibers have been synthesized, isokinetic exercise also assists with their remodelling along lines of force that are appropriate to the site of injury repair. A parallel alignment of fibers is facilitated, which helps to increase the static strength of the collagen and to build a flexible tissue mass rather than an inflexible, dysfunctional scar (5). The overall effect helps to speed the process of rehabilitation through the shortening of the period of tissue repair. This connective tissue adaptation could also be achieved through any other form of progressive resistance exercise (5).

## MUSCLE ADAPTATIONS

Isokinetic exercise induces muscle hypertrophy. Hypertrophication occurs over a minimum of eight weeks of training, similar to the effects which accompany progressive resistance exercise (1,2). The adaptation process occurs at the cellular level through enhancement of the process of protein synthesis (2). Just as isokinetic exercise stimulates fibrocytes in con-

nective tissue to produce more cellular proteins that are then synthesized into collagen for structural repair, isokinetic activity also stimulates myocytes in the lumbar muscle groups to produce more actin and myosin proteins for repair and improvement of the contractile apparatus (1,2). It has also been theorized that isokinetic training, as well as other types of muscle exercise, might enhance the specific development of Type II (fast twitch) muscle fibers or stimulate mutagenesis between muscle fiber types: Type I fibers become more like Type II fibers revert to Type I fibers (1,2). This potential for influence on muscle fiber type would be a function of the specific mechanism and format of muscle training and has yet to be demonstrated distinctly for isokinetic exercise.

## NEUROLOGICAL ADAPTATIONS

Isokinetic exercise enhances muscle performance through adaptations which occur in the neural component of the alpha motor neuron system. Isokinetics enhance the degree of a subject's maximal volitional contraction, which is represented as an increased level of MEG activity during exercise (7). The effect may occur as a function of a more synchronous discharge of motor neurons within a muscle complex, of a lowered threshold for the activation of the excitation contraction-coupling process, of a dampening of inhibitory reflexes, of an increase in sympathetic nervous system activity, or as a combination of neuromuscular events (7). The effect also parallels the known influences which progressive resistance exercise has upon the neurological system and is responsible for the early gains in muscle performance that cannot be attributed to muscle hypertrophy (7). Although significant muscle changes are not manifest without at least eight weeks of isokinetic training, many subjects demonstrate improvement in their muscle power, torque and work performance ability in much less time. These gains are a product of the neural component of the alpha motor neuron system and not the contractile component (7).

Isokinetic exercise also facilitates another interesting phenomenon which is known as accessing a muscle's functional reserve. Although an individual may generate a high level of muscle force output during a maximal volitional contraction that output level is relatively minimal compared to the absolute force production capacity of a muscle. The maximal volitional level for force production in most muscles is only 30% of their absolute contractile potential (1,7). The difference between a muscle's absolute capacity for force production and the level of a maximal volitional contraction is known as the functional reserve (absolute capacity - maximal volitional capacity = functional reserve). The functional reserve reflects the inhibitory and protective influence of the neurological system upon the musculoskeletal system which prevents the volitional potentiation of an absolute level of muscle contractile force (7). If a maximal volitional effort approached the level of a muscle's absolute capacity for force generation then articular, musculoskeletal or myotendinous damage would occur to create a state of injury. Conversely, however, the functional reserve also represents a 70% region for the potential enhancement of neuromuscular efficiency. Isokinetic training

promotes such efficiency through accessing the performance potential of the functional reserve to allow higher level for maximal volitional muscle performance (7). Although the level of access is not significant enough to approach a muscle's maximum capacity and, therefore, risk tissue injury, enhancement may achieve a 50% level of absolute capacity which translates to an overall enhanced potential for the efficient performance of human motor tasks (1,6,7).

### OSSEOUS ADAPTATIONS

Isokinetic exercise induces changes in bone that are an application of Wolff's Law of tissue remodelling and of the SAID principle: living tissue will adapt as a direct response to specific external demands (2,5). This adaptation, which is also manifest in the process of connective tissue adaptation to isokinetic exercise, takes place to physically strengthen bone in order to make it more resistant to external force loads that may inflict tissue injury (5). Specifically, isokinetic exercise of at least eight weeks duration enhances the strength of bone through increases in bone density, bone mass and bone mineral content (5). These effects occur as a function of an increase in protein synthetic activity by osteoblasts, a relative inhibition of osteoclastic activity and enhancement of calcium and vitamin D metabolism within the skeletal system (2,5). Similar effects may result from most forms of progressive resistance and aerobic exercise (2,5).

An interesting, but largely unstudied, potential application of this physiological adaptation would be the use of isokinetic exercise as an adjunct in the treatment of patients with osteoporosis, or other pathological states involving abnormalities in osseous metabolism. The accommodating resistance of isokinetic activity would control against the application of excessive and injurious forces to the lumbar spine while the overall exercise effect might promote a greater degree of osseous integrity through increases in bone density, mass and mineral content. This would represent a direct means for the use of Wolff's Law through isokinetic technology for the effective remodelling of injured tissue. This idea, however, is largely theoretical and much research needs to be accomplished in order to completely elucidate the efficacy of its potential for patient care.

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# POSTSURGICAL KNEE REHABILITATION

A FIVE YEAR STUDY OF FOUR METHODS AND 5,381 PATIENTS

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## ABSTRACT

This study was an investigation into the influences of rehabilitation procedures on the long-term success postsurgical knee patients. In a blind retrospective paradigm, the cases of 5,381 patients (2,417 females / 2,964 males / mean age, 32.7 years / age range 13 to 61 years) were reviewed to correlate rehabilitation methods with post-surgical success. Postsurgical success was defined as patient resumption of required activities without symptom recurrence, over a period of 5 years after surgery. The four rehabilitation methods studied were programs of no exercise, home exercise, isotonic exercise, and isokinetic exercise. Statistical analysis revealed significant differences at the  $P=0.05$  level for comparison of the isokinetic exercise to the other methods on the basis of rehabilitation interval (isokinetic,  $8.9 \pm 3.7$  weeks; isotonic,  $12.3 \pm 6.1$  weeks; home,  $10.0 \pm 4.5$  weeks) and correlation to success (isokinetic,  $r = 0.92$ , isotonic,  $r = 0.48$ , home,  $r = 0.09$ , no exercise,  $r = 0.00$ ). It was concluded that rehabilitation methods that incorporate isokinetic exercise are more efficient and effective than nonisokinetic programs in the long-term successful management of postsurgical knee patients.

The literature contains many long-term follow-up studies of knee surgery patients. Cross and Powell,<sup>1</sup> Moretz et al.,<sup>2</sup> Odensten et al.,<sup>3</sup> and Whipple et al.<sup>4</sup> precisely describe surgical procedures, postsurgical activities, surgical success statistics, and rates of problem recurrence. They do not, however, address the rehabilitation process as a factor in the postsurgical results of knee patients.

Although some studies, such as those of Sutter and Tegner et al.<sup>5</sup> do mention rehabilitation methods, the literature remains ambiguous regarding the efficacy of appropriate rehabilitation methods following knee surgery. Advancement in the knowledge of effective rehabilitation methods is necessary since rehabilitation success will ultimately determine surgical success.

This study was undertaken to investigate the influence of rehabilitation methods on the postsurgical success of knee patients. Using a retrospective and descriptive paradigm, the histories of postsurgical knee patients were examined in an effort to correlate surgical diagnosis, rehabilitation methods, and postsurgical success. Postsurgical success was defined as patient resumption of activities of daily living and recreational activities without pain or symptom recurrence. This definition was adopted since the success of any rehabilitation program is based on the return of a patient to a presurgical level of physical function.

## MATERIALS AND METHODS

### Subjects

The medical records of 5,381 knee patients (2,417 females / 2,964 males / mean age, 32.7 years / age range, 13 to 61 years) were retrospectively studied. All of the patients had been operated on in 1981 and were then followed up by their physicians as necessary or appropriate through 1986. All of the medical records, which were secured from seven hospitals in Michigan, Ohio, and Pennsylvania, were blinded in order to maintain

patient, physician, and hospital confidentiality. Operative diagnoses and surgical procedures fell into the following categories: arthroscopic medial meniscectomy (1,625 patients, 30%), arthroscopic lateral meniscectomy (1,143 patients, 21%), arthroscopic lateral retinacular release (106 patients, 2%), arthroscopic patellofemoral shaving for chondromalacia (221 patients, 4%), arthroscopic plica excision (283 patients, 5%), medial collateral ligament repair (1,206 patients, 22%), and lateral collateral ligament repair (797 patients, 15%).

## Procedures

The medical records of each subject were examined for the following factors: method of postsurgical rehabilitation; time interval required for rehabilitation; parameters for discharge from rehabilitation, surgical, and rehabilitative success; and method of follow-up treatment, if necessary. Data compiled on these factors were then subjected to statistical analyses using chi square, Pearson correlation, and t-test methods at the  $P = 0.05$  level of significance. The null hypothesis that the Postsurgical knee rehabilitation methods that were used would have no effect on patient success after surgery was assumed for statistical testing purposes.

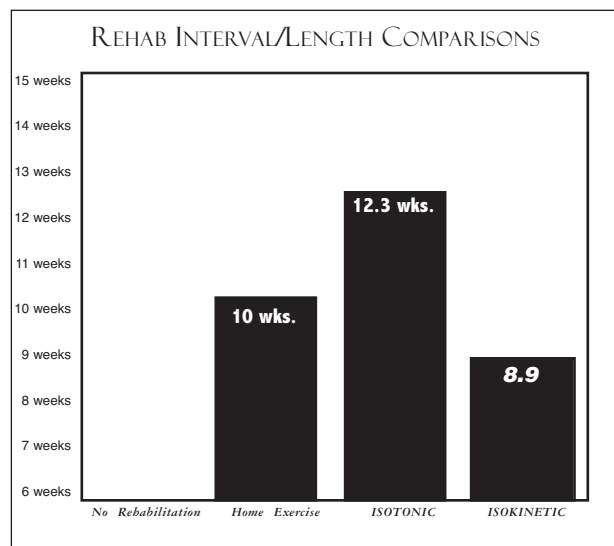
## RESULTS

### Rehabilitation Methods

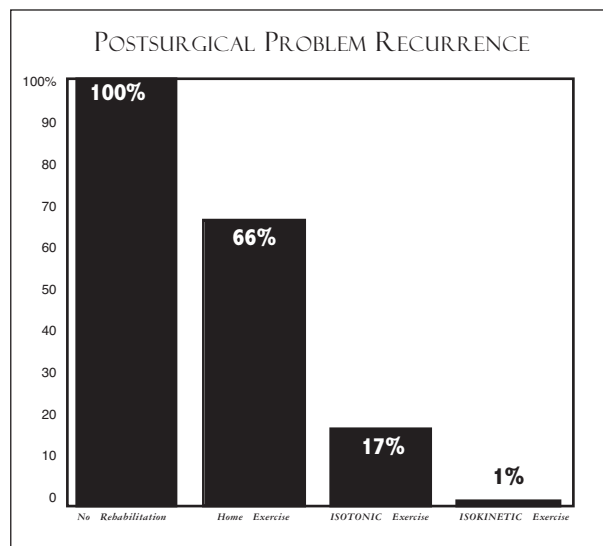
Although diversity existed in the specific treatment of individual patients, standardized protocols were used at each of the seven hospitals. Four methods of rehabilitation were used: no rehabilitation (108 patients, 2%), home exercise (1,346 patients, 25%), isotonic exercise (2,261 patients, 42%), and isokinetic exercise (1,666 patients, 31%). Of the patients in the no rehabilitation category, 58 had arthroscopic patellofemoral shavings for chondromalacia (54% of the 108 patients; 26% of the 221 patients in the diagnostic category), 36 had arthroscopic lateral retinacular releases (33%; 34%), and 14 had arthroscopic plica excisions (13%; 5%). The no rehabilitation category was defined as lack of any form of formal or informal instruction for patient exercise or reconditioning postsurgically.

Of the home exercise patients, 241 had arthroscopic medial meniscectomy (18% of the 1,346 patients; 15% of the 1,625 patients in the diagnostic category), 227 had arthroscopic lateral meniscectomy (17%; 20%), 42 had arthroscopic lateral retinacular release (3%; 40%), 224 had medial collateral ligament repairs (17%; 18%), 211 had lateral collateral ligament repairs (15%; 26%), 147 had arthroscopic patellofemoral shavings for chondromalacia (11%; 66%), and 254 had arthroscopic plica excisions (19%; 90%). The home exercise category was defined as patient instruction in a program of reconditioning exercises that were to be performed at home without formal monitoring of the patient. In general, the programs consisted of 3 sets of 10 repetitions each of quadriceps and hamstrings isometric setting, straight leg raising, terminal knee extension/short arc quadriceps, hamstrings curl, and toe/heel raising exercises performed on a three times per day basis that is similar to the formats of Malone et al. and Miller and Hembra.

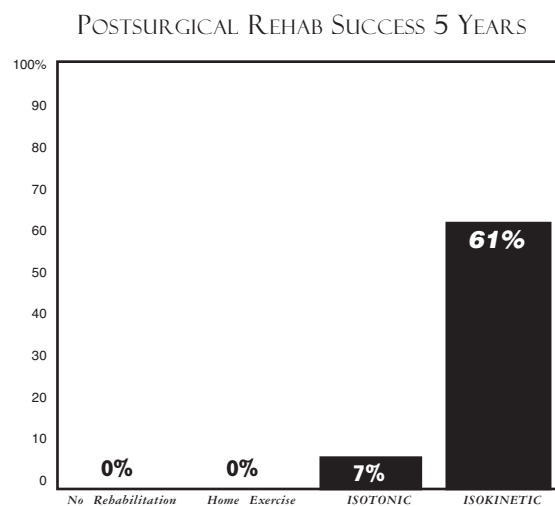
# POSTSURGICAL KNEE REHABILITATION STUDY



Shown above, the rehabilitation intervals required during this study.



This chart demonstrates the % of patients who reported a recurrence of the initial problem, or a continuation of presurgical knee problems within the first postsurgical year.



Shown above, the % of rehabilitation success as defined as patient's resumption of normal activity without pain or symptom recurrence over the 5-year period.

*A five-year study of four methods and 5,381 patients by Kent E. Timm, PhD, PT, ATC, Saginaw Michigan, as printed in The American Journal of Sports Medicine, Vol. 16, No. 5.*

Of the 2,261 isotonic exercise patients, 10 had arthroscopic plica excisions (less than 1% of the 2,261 patients; 4% of the 283 patients in the diagnostic category), 8 had arthroscopic patellofemoral shavings for chondromalacia (less than 1%; 4%), 19 had arthroscopic lateral retinacular releases (1%; 18%), 748 had arthroscopic medial meniscectomies (33%; 46%), 512 had arthroscopic lateral meniscectomies, (23%; 45%), 601 had medial collateral ligament repairs (26%; 50%), and 363 had lateral collateral ligament repairs (16%; 46%). The isotonic exercise category was defined as patient participation in formal programs of postsurgical rehabilitation, primarily involving isotonic activities, under the supervision of a physical therapist and/or an athletic trainer. In general, the programs incorporated a regimen of calisthenic and isometric exercises, which paralleled the aforementioned home exercise program, and advanced to progressive resistance concentric and eccentric isotonic exercises using leg weights, free weights, or variable resistance weight machines performed on a three to four session per week basis, similar to the protocols of Darden, DeLorme, Miller and Hemba, and Nosse and Hunter.

Of the 1,666 isokinetic exercise patients, 636 underwent arthroscopic medial meniscectomy (38% of the 1,666 patients; 37% of the 1,625 patients in the diagnostic category), 404 had arthroscopic lateral meniscectomies (24%; 35%), 9 had arthroscopic lateral retinacular releases (less than 1%; 8%), 381 had medial collateral ligament repairs (23%; 32%), 223 had lateral collateral ligament repairs (13%; 28%), 8 had arthroscopic patellofemoral shavings for chondromalacia (less than 1%; 4%), and 5 had arthroscopic plica excisions (less than 1%; 2%). The rehabilitation category was defined as patient participation in formal programs of postsurgical rehabilitation that emphasized isokinetic activities conducted under the supervision of a physical therapist in a three sessions per week format. In general, the programs were sequenced in stages beginning with a regimen of calisthenic and isometric exercises that parallel the home exercise program. The programs were advanced to incorporate progressive resistance concentric and eccentric isotonic exercises, similar to the isotonic programs, complemented by bicycle ergometry and proprioception exercises. The programs then progressed to isokinetic exercise complemented by therapeutic exercises that simulated the functional activities required by the patients. All of the rehabilitation programs paralleled the protocols of Davies, Quillen, Sherman et al, Smith and Melton, Sutter, Timm and Patch, and Zarins et al.

#### **Discharge Parameters**

The patients in the no rehabilitation and home exercise categories had no specific parameters for discontinuation of postsurgical rehabilitation, since neither program involved formal supervision. The parameters for discharge from the isotonic program included bilateral equivalence of leg muscle girth based on anthropometric measurements at 2, 4, and 6 inches above and 4 inches below the patella; full, painless knee range of motion; and the ability to perform activities of daily living and/or athletic activities without loss of joint stability. The discharge parameters for the isokinetic program included attainment of a 90% or higher level of quadriceps and hamstrings performance factors of peak torque, peak torque to body weight ratio, peak torque acceleration energy, endurance ratio, watts average power, agonist-antagonist peak torque ratio, and agonist-antagonist work ratio in bilateral comparison to the noninjured knee across a spectrum of functional speeds; and ability to perform daily, occupational and/or athletic activities without knee discomfort and joint instability.

#### **Rehabilitation Intervals**

This designation did not apply to patients in the no rehabilitation category since they were not involved in a program of postsurgical rehabilitation. Patients in the home exercise category reported an average of  $10 \pm 4.5$  weeks of rehabilitation from the time of surgery until the point of subjective satisfaction with postsurgical results, symptom recurrence, or disinterest in program continuation. The isotonic program patients required a mean interval of  $12.3 \pm 6.1$  weeks in rehabilitation until their parameters for discharge were attained. The patients in the isokinetic exercise category required a period of  $8.9 \pm 3.7$  weeks to meet their discharge parameters.

#### **Rehabilitation Success and Problems Recurrence**

All 108 patients (100%) in the no rehabilitation category reported a return of initial symptoms or a continuation of presurgical knee problems within the 1st postsurgical year. This represents a surgical and rehabilitative success rate of 0%, since success was defined as patient resumption of normal activities without pain or symptom recurrence. All of these patients underwent follow-up rehabilitation consisting of either isotonic exercise (62 patients; 31 arthroscopic shavings for chondromalacia, 18 lateral retinacular releases, and 13 arthroscopic plica excisions) or isokinetic exercise (46 patients; 27 arthroscopic patellofemoral shavings for chondromalacia, 18 lateral retinacular releases, and 1 arthroscopic plica excision).

Of the 1,346 home exercise patients, 888 (66%) reported a return of symptoms and/or problems within the 1st postsurgical year, 337 (25%) within the 2nd postsurgical year, and the remaining 121 (9%) within third postsurgical year. These findings represent 1, 2, 3, 4, and 5 year success rates of 34%, 9%, 0%, 0%, and 0%, respectively. At followup, all of the patients were put on isotonic exercise programs (808 patients; 167 arthroscopic medial meniscectomies, 126 arthroscopic lateral meniscectomies, 22 arthroscopic lateral retinacular releases, 121 medial collateral ligament repairs, 93 lateral collateral ligament repairs, 116 arthroscopic patellofemoral shavings for chondromalacia, and 163 arthroscopic plica excisions) or isokinetic exercise programs (538 patients; 74 arthroscopic medial meniscectomies, 101 arthroscopic lateral meniscectomies, 20 arthroscopic lateral retinacular releases, 103 medial collateral ligament repairs, 118 lateral collateral ligament repairs, 31 arthroscopic patellofemoral shavings for chondromalacia, and 91 arthroscopic plica excisions) as additional rehabilitation.

Of the 2,261 isotonic exercise patients, 389 (17%) reported a return of symptoms and/or problems within the 1st postsurgical year, 617 (27%) within the 2nd postsurgical year, 539 (24%) within the 3rd postsurgical year, 362 (16%) within the 4th postsurgical year, and 185 (8%) within the 5th postsurgical year. A total of 169 patients (7%) had no complaints of knee pain or problems at 5 years postsurgery. These findings represent 1, 2, 3, 4, and 5 year success rates of 83%, 56%, 32%, 16%, and 7%, respectively. Of the 2,092 patients who experienced a return of knee problems within 5 years of surgery, 628 (4 arthroscopic plica excisions, 2 arthroscopic patellofemoral shavings for chondromalacia, 8 arthroscopic lateral retinacular releases, 224 arthroscopic medial meniscectomies, 154 arthroscopic lateral meniscectomies, 180 medial collateral ligament repairs, and 56 lateral collateral ligament repairs) were returned to a program of isotonic rehabilitation, and 1,464 (6 arthroscopic plica excisions,



6 arthroscopic patellofemoral shavings for chondromalacia, 11 arthroscopic lateral retinacular releases, 524 arthroscopic medial meniscectomies, 358 arthroscopic lateral meniscectomies, 421 medial collateral ligament repairs, and 138 lateral collateral ligament repairs) were placed on an isokinetic exercise program.

Of the 1,666 isokinetic exercise patients, 21 (1 %) reported a return of symptoms and/or problems within the 1st postsurgical year, 145 (9%) within the 2nd postsurgical year, 177 (11%) within the 3rd postsurgical year, 201 (12%) within the 4th postsurgical year, and 102 (6%) within the 5th postsurgical year. A total of 1,020 patients (61%) were without complaints of knee pain or problems at 5 years postsurgery. These findings represent 1, 2, 3, 4, and 5 year success rates of 99%, 90%, 79%, 67%, and 61%, respectively. All of the 646 patients who experienced a return of knee problems (254 arthroscopic medial meniscectomies, 162 arthroscopic lateral meniscectomies, 152 medial collateral ligament repairs, 77 lateral collateral ligament repairs, and 1 patellofemoral shaving for chondromalacia) were returned to a program of isokinetic exercise.

#### Follow-Up Success

Follow-up rehabilitation was necessary for 4,146 of the 5,381 patients involved in this study (77%) under isotonic or isokinetic exercise methods. Isotonic methods were used on 1,498 patients (62 from the no rehabilitation category, 808 from the home exercise category, and 628 from the isotonic exercise category; 149 arthroscopic patellofemoral shavings for chondromalacia, 48 arthroscopic lateral retinacular releases, 180 arthroscopic plica excisions, 391 arthroscopic medial meniscectomies, 280 arthroscopic lateral meniscectomies, 301 medial collateral ligament repairs, and 149 lateral collateral ligament repairs). An isokinetic exercise program was used with 2,648 patients (538 from the home exercise category, 1,464 from the isotonic exercise category, and 646 from the isokinetic exercise category; 38 arthroscopic patellofemoral shavings for chondromalacia, 31 arthroscopic lateral retinacular releases, 97 arthroscopic plica excisions, 852 arthroscopic medial meniscectomies, 621 arthroscopic lateral meniscectomies, 676 medial collateral ligament repairs, and 333 lateral collateral ligament repairs).

Of the 1,498 isotonic exercise patients 225 (15%; 97 arthroscopic medial meniscectomies, 63 medial collateral ligament repairs, 6 arthroscopic shavings for chondromalacia, 5 arthroscopic lateral retinacular releases, 13 arthroscopic plica excisions, 20 arthroscopic lateral meniscectomies, and 21 lateral collateral ligament repairs) experienced a return of initial or secondary, pre-follow-up treatment symptoms within the 1st year of follow-up, 343 (23%; 19 arthroscopic patellofemoral shavings for chondromalacia, 6 arthroscopic lateral retinacular releases, 18 arthroscopic plica excisions, 130 arthroscopic medial meniscectomies, 57 arthroscopic lateral meniscectomies, 76 medial collateral ligament repairs, and 37 lateral collateral ligament repairs) within the 2nd year of followup, and 315 (21%; 114 arthroscopic medial meniscectomies, 88 medial collateral ligament repairs, 71 arthroscopic lateral meniscectomies, and 42 lateral collateral ligament repairs) within the 3rd year of followup.

These figures represent 1, 2, and 3 year follow-up success rates of 85%, 62%, and 41%, respectively. The 883 patients (59%) who experienced a return of problems were placed at followup in another rehabilitation program that consisted of isokinetic exer-

cise; their results were not known by the end of the study period. The remaining 615 patients (41%) either did not complete their follow-up isotonic rehabilitation or did not report a return of problems within the 5 year study period.

Of the 2,648 isokinetic exercise patients, 25 (1%; 2 arthroscopic patellofemoral shavings for chondromalacia, 1 arthroscopic plica excision, 12 arthroscopic medial meniscectomies, 3 arthroscopic lateral meniscectomies, and 7 medial collateral ligament repairs) experienced a return of initial or secondary, pre-follow-up treatment symptoms within the 1st year of followup, 186 (7%; 59 arthroscopic medial meniscectomies, 38 arthroscopic lateral meniscectomies, 47 medial collateral ligament repairs, and 42 lateral collateral ligament repairs) within the 2nd year of followup and 212 (8%; 1 arthroscopic patellofemoral shaving for chondromalacia, 1 arthroscopic plica excision, 69 arthroscopic medial meniscectomies, 44 arthroscopic lateral meniscectomies, 76 medial collateral ligament repairs, and 21 lateral collateral ligament repairs) within the 3rd year of followup.

These figures represent 1, 2, and 3 year follow-up success rates of 99%, 92%, and 84%, respectively. The remaining 2,225 patients (84%) either did not complete their follow-up isokinetic rehabilitation or did not report a return of problems within the 5 year study period.

#### Statistical Analysis

T-tests, as summarized in Table 1, revealed statistically significant differences between the home exercise, isotonic exercise, and isokinetic exercise programs on the basis of rehabilitation interval at the  $P = 0.05$  significance level.

TABLE 1  
T-test evaluation

Test	t Value
Isotonic program vs. home program	6.76
Isokinetic program vs. home program	10.00
Isokinetic program vs. isotonic program	7.56
Critical t value ( $P = 0.05$ )	1.73

TABLE 2  
Pearson test evaluation

Rehabilitation program	r Value
No exercise	0.00
Home exercise	0.09
Isotonic exercise	0.48
Isokinetic exercise	0.92
Critical r value ( $P = 0.05$ )	0.90

Pearson testing (Table 2), which correlated the rehabilitation method to the overall success rate within the 5 year study period, demonstrated a significant correlation between the isokinetic exercise program and postsurgical success at the  $P=0.05$  significant level, whereas the no exercise, home exercise, and isotonic exercise programs yielded relationships that were not significantly correlated with success.

Chi square tests (Table 3), which examined the postsurgical success rates of each rehabilitation method across the 5 year study period, revealed the absence of a significant difference between the no exercise and home exercise programs, a statistically sig-

nificant difference between these two programs and the isotonic exercise program, and a significant difference between the isokinetic exercise program and each of the other three rehabilitation methods, each at the  $P=0.05$  level.

## DISCUSSION

Based upon the results, the isokinetic exercise program was determined to be the most effective of the four methods examined in this study. The isokinetic program was significantly different from the other methods in terms of the rehabilitation interval, 8.9 weeks compared to 10 weeks for the home programs, and 12.3 weeks for the isotonic programs. In terms of initial rehabilitation success over the 5 year period, the isokinetic program's success rate was 61% compared to 7%, 0%, and 0% for the isotonic, home exercise, and no exercise programs, respectively. The isokinetic program had an 84% success rate in follow-up treatment over 3 years, versus 41% for the isotonic exercise program. In overall rehabilitation success, the isokinetic program produced a 0.92 correlation factor compared to correlation of 0.48, 0.09, and 0 for the isotonic, home exercise, and no exercise programs, respectively. This identifies isokinetic exercise as the most efficient and effective rehabilitation method for postsurgical knee rehabilitation.

The effectiveness of isokinetic exercise is based on several physiologic factors. Isokinetic activity enhances performance ability by optimizing neuromuscular responses to exercise through the decrease of alpha motoneuron inhibition, the promotion of motor unit contraction synchrony, the facilitation of maximal muscle contraction at each point in an available joint range of motion, the increase in muscle fiber and motor unit recruitment, the increase in speed of actinomyosin crossbridge formation, and the stimulation of both slow twitch and fast twitch muscle fiber types as related to the principles of accommodating resistance across a variable spectrum of fixed exercise velocities. These factors are in contrast to the physiologic aspects of isotonic exercises, which is the major component of each of the three rehabilitation methods examined in this study, especially on the basis of muscle fiber type effects.

TABLE 3  
Chi square test evaluation

Test	Chi square value
Home program vs. no exercise program	7.16
Isotonic program vs. no exercise program	146.78
Isotonic program vs. home program	103.49
Isokinetic program vs. no exercise program	396.00
Isokinetic program vs. home program	322.58
Isokinetic program vs. isotonic program	163.77
Critical value ( $P=0.05$ )	12.02

Isotonic exercise is submaximal work, since optimum concentric or eccentric muscle loading occurs only at the extremes of the exercise motion pattern, which selectively facilitates slow twitch muscle fiber performance abilities without significant effects upon fast twitch fiber functions. Isotonic activity is effective for slow twitch fiber strengthening but, because quadriceps fast twitch muscle fiber area may be decreased as much as 30% in the postsurgical leg, it cannot be as effective as isokinetic exercise, which promotes an increase in mean and relative fast twitch fiber area, for the thorough rehabilitation of the postsurgical knee.

Although some clinicians advocate the use of eccentric isotonic activity over the use of isokinetic exercise for muscle rehabilitation, because of the increased intensity level of contractile forces, the effect is still specific to slow twitch muscle fibers. Interestingly, one recent study has indicated that concentric isokinetic exercise can enhance eccentric muscle performance in a magnitude similar to that of eccentric exercise while still facilitating fast twitch fiber actions.

While increased muscle function of any type will enhance tissue healing by decreasing the load forces applied to the surgical site, muscles trained isotonically will regress once rehabilitation is ended, predisposing a patient to injury or to symptom recurrence. Muscles worked isokinetically retain optimal function once training has ceased. This idea is reflected in the postsurgical rehabilitation success of the isokinetically rehabilitated patients in this study.

Isokinetic effectiveness is also based on metabolic and skeletal factors. Isokinetic activity involves both the aerobic and anaerobic energy systems and enhances the production of supportive glycolytic and oxidative enzymes, whereas other exercise systems typically and preferentially use only one energy system. Isokinetic exercise, especially at fast velocities, decreases joint compression forces, facilitates synovial joint lubrication, and enhances normal joint osteokinematics and arthrokinematics. These factors, along with the aforementioned physiologic characteristics, permit isokinetic rehabilitation systems to promote neuromuscular integrity, to approximate the musculoskeletal forces that are associated with normal actions of daily living, and to efficiently simulate functional activities. The potential for an activity that simulates a patient's functional requirements and specifically adapts the neuromusculoskeletal systems of the surgical area to the imposed demands of normal joint and muscle actions are the keys for establishing the effectiveness of isokinetic exercise programs in the successful long-term rehabilitation of postsurgical knee patients.

Although isokinetic exercise was the major emphasis of the isokinetic exercise program examined in this study, the program did encompass most aspects of the other rehabilitation methods, with the exception of the no exercise program. Patients were started on a regimen of calisthenic and isometric exercises, similar to the home exercise program, and were advanced to progressive resistance concentric and eccentric isotonic exercises, parallel to the isotonic protocol, before progression to isokinetic activities, proprioception developing activities, and functional simulation. The rehabilitation scheme is thus a sequence of staged components in which the resultant effectiveness of the final form, isokinetic exercise, is built upon the progression through isometric, calisthenic, and isotonic activities. This may explain the lack of rehabilitation success for the other methods, especially relative to the general trend that the more involved surgical procedures, such as medial collateral ligament repairs, had quicker symptom recurrence without isokinetic rehabilitation; they did not reach the isokinetic end point and had discharge parameters based upon subjective interpretation or anthropometric measures rather than functional capability. The objective measurements involved with monitoring patient status, progressing program intensity, and finally, discharging patients from the rehabilitation process might also underscore the relative success of the integrated rehabilitation process. The isokinetic patients passed through all stages of



the rehabilitation sequence, were discharged only after attainment of functional normalcy, and, therefore, responded more successfully to surgery and to rehabilitation.

Although the various aspects of postsurgical knee rehabilitation were carefully examined and did generate several tenable results regarding the effectiveness of isokinetic exercise, various threats to reliability and validity existed in the study. Since the study was retrospective in nature, and also lacking in procedural randomization methods, the results, although statistically significant, cannot be interpreted with the same degree of precision as results from a more formal research methodology for generalization to a broader population of knee patients. Other potential threats to experimental reliability and validity include possible variations in the specific components and sequences of the four rehabilitation methods, in surgical technique and clinical expertise, in patient motivation and physiologic healing rates, and in the mechanics of the isotonic and isokinetic equipment employed during rehabilitation. Also, this study examined only selected knee abnormalities and did not investigate other problems, such as ACL disorders, which may have yielded different results. Potential for variation in results also stems from the fact that not all of the patients completed the follow-up rehabilitation programs within the 5 year study. Formal experimental research is currently being directed toward the further investigation of these specific areas and of the general aspects of postsurgical knee rehabilitation.

## CONCLUSIONS

Based upon the results, but within the limitations of the experimental design of this investigation, it may be concluded that rehabilitation programs that incorporate isokinetic exercise are more efficient and effective than programs that do not include isokinetic activity for the long-term successful rehabilitation of postsurgical knee.

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# PROVIDING THE RIGHT RESISTANCE

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An enormous number of tools are available to the clinician to provide resistance training during rehabilitation. From free weights and dumbbells to resistive weight machines, equipment manufacturers provide the physical therapist with several options to augment a hands-on approach. Perhaps the pinnacle of this technological evolution is the isokinetic device.

The advent of isokinetics, as both a mode of exercise and a device on which this exercise can be performed, began in the mid-1960's. A number of researchers and clinicians published articles during this time describing this new form of resistance training, most notably James Perrine, Helen Hislop and Mary Moffroid. Their early prototypes evolved into the machines we use today. There are several different units available, including hydraulic devices as well as computerized devices. These systems are used for extremity and lumbar testing and rehabilitation and provide quantitative objective data, which helps to formulate clinical outcomes.

## The I's of Exercise

Exercise can be divided into three categories: isometric, isotonic and isokinetic. But the concept of isokinetics will be easier to understand if we first examine the biomechanical principles of each.

The two exercise variables that we will use to compare the three types of exercise will be resistance (force) and speed of movement (angular velocity). In isometric exercise, the resistance is so great that there is no movement in the joint. Due to the inability of the contracting muscles to overcome this force, angular velocity is considered to be 0 degrees per second. Isotonic exercise can be best described using free weights. In this instance the resistance is fixed (the weight of the barbell), but the speed of movement varies according to the individual. This is usually performed at an angular velocity of approximately 60 degrees per second. Isokinetics is a unique form of strength training in which the resistance varies according to the individual, but the speed of movement is fixed. In other words, the force varies according to how hard the patient works. If the angular velocity is fixed, the patient can never overcome the speed set on the machine. The greater the force he or she expends during an exercise bout, the more resistance.

## High-Tech Isokinetics

There are a number of advantages to isokinetic exercise when compared to isometric and isotonic exercise. As examined above, isokinetics maximally loads the exercising muscle throughout the range of motion, as opposed to isotonic, which loads the muscle at its weakest position in the range of motion. There is also an inherent safety factor in that the resistance will never be greater than what the patient can tolerate.

Isokinetic devices can be found in a variety of facilities, but mainly in outpatient orthopedic settings. This form of exercise can be used to treat a large percentage of orthopedic injuries and dysfunctions including rotator cuff tears and impingement syndromes in the shoulder, lateral epicondylitis at the elbow, ligamentous and meniscal pathologies in the knee, lateral ligamen-

tous injuries and achilles tendinitis at the ankle. Isokinetics are also used postoperatively to restore normal muscle strength, power and endurance. They can also be used in lieu of a continuous passive motion device to restore normal range of motion and decrease the debilitating effects of immobility. As mentioned earlier, isokinetics have also been used to treat some back pathologies including lumbar sprains and strains. But due to the complex arthrokinematics and thoracolumbar musculature, it has not been as widely used as the extremity units.

How can one machine do all this? Isokinetic devices are computerized for quick access to rehabilitation and testing protocols and contain an array of attachments. Once range of motion, pain and effusion goals have been established, the clinician can perform an isokinetic test to determine the objective strength and endurance of the involved vs. the uninvolved extremity.

The objective data received during an isokinetic test can allow the clinician to gauge a patient's progress during the rehabilitation process. A few of the parameters that are objectively quantified are the peak torque, total work, power and agonist/antagonist musculature ratio. The peak torque is a measure of the greatest force output during the testing bout.

This is usually performed with a set of five repetitions, and the angular velocities range from 30 to 180 degrees per second. Total work is a cumulative measure of the force and range of motion performed on each repetition in a testing bout. This can be performed using 15 repetitions and angular velocities of 240 to 450 degrees per second.

Peak torque is often used as a value for strength, and total work delineates endurance in the musculature being tested. Power is a more functional measurement, based on the person's ability to perform the greatest amount of work in the shortest period of time. Finally, agonist/antagonist musculature ratios have been developed through extensive testing of normal subjects, and allows the clinician to see muscular imbalances that may cause disastrous consequences upon return to functional activity.

## Pre-Testing

Testing protocols have other applications that may be extremely important to the clinician. For instance, during pre-season athletic screenings at the high school, college and professional level, a clinician may determine results about an athlete's ability to safely participate in his or her sport.

Pre-employment screenings are another isokinetic testing application that has seen increased popularity. For example, after patients sustain a work-related injury, the screenings can provide the therapist with a tool to identify patients who may have other motivations for not giving 100 percent effort in their rehabilitation.

This is especially useful with Worker's Compensation cases. A reproducibility curve (test/re-test) for reliability can be run, may identify symptom magnifiers.

### **Form and Function**

Although isokinetic exercise has widespread applications in numerous settings, it does have its limitations. Isokinetics provides the clinician with an excellent tool for resistance training after injury, unfortunately, we do not function isokinetically. Yet achieving a normal test score when compared to the uninjured extremity is an excellent precursor to participate in functional activity. Another interesting concept is the fact that isokinetic exercise is an open chain action by nature. Again, as human beings, we do not function in a chain, or act at a constant angular velocity. These machines can reach speeds of only 450 degrees per second, whereas an athlete's shoulder during a tennis serve or pitching a baseball can reach angular velocities of approximately 4,000 to 7,000 degrees per second.

### **Justifying Costs**

If you're considering purchasing an isokinetic device, keep a few things in mind. First, these devices can be high-tech, and extremely expensive. But with the variety of rehabilitation and test protocols available on each machine, and the ability to perform metric, isotonic (concentric and eccentric) and isokinetic formal exercise, they may well be worth the expense. I suggest performing a market survey prior to your purchase, including locating facilities in your area that offer this service. Another factor to examine is the ability to receive reimbursement for using this device with your patient population. Communicating with your insurance companies and CPT coding may eliminate any concerns of this nature.

Isokinetics are proven to be a valuable part of the rehabilitation process. When used as an adjunct to the total program, it can provide the clinician with numerous opportunities in which to achieve their patients' goals. This unique form of exercise has proven extremely effective in restoring non-muscular strength, power and endurance to an injured body part.

Several researchers are now examining the relationship between isokinetics and functional exercise such as the single leg hop or vertical leap. A number of protocols have been established for treating specific pathologies. But isokinetics should not be used in a cookbook approach. The computer programs on these devices are easily understood and will extend the clinician's expertise in providing the highest quality of care to your patient population. Patients appreciate the verbal feedback and objective recording of data that gauge their progress.

Isokinetic devices would be an excellent addition to any facility treating a caseload that's appropriate for this type of exercise. And also may decrease the need for other types of sophisticated resistive equipment. Cost, reimbursement issues and market demand will always be important factors to consider in your search for appropriate equipment for your facility.

# ISOKINETICS: OPTIMAL USE IN SPORTS MEDICINE PHYSICAL THERAPY FACILITIES

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Over the past several years, countless changes in rehabilitation protocols and surgical procedures have fostered an attitude of "progressive" physical therapy among today's leading clinicians. Due to the respective advances in patient care, clinicians now see both post-surgical and conservatively managed patients sooner. Ultimately, this enables patients to return to the activities of daily living, work, or sport far earlier than in the past with reduced odds of encountering recurrent symptoms. Standard techniques such as PNF, joint mobilizations, massage, electro-therapy, flexibility training, etc., are also undergoing fundamental changes.

Even while this progressive revolution has been underway, an ever-building volume of research provides clinicians the means necessary for developing progressive physical therapy protocols. These "progressive" protocols not only return the patient to activity sooner, but provide a safer means of return as well. Proof of this is demonstrated by the changes associated with ACL reconstructions. In the mid-1980's, post-op ACL reconstructions were discharged, following a lengthy hospital stay, with a full-leg cast locking the knee at 30 degrees of flexion to prevent graft deterioration and decreased soft tissue trauma. Although initiated with good intentions, we now know such positioning and immobilization to be deleterious to the joint surfaces. Locking patients at 30 degrees of flexion increases the total time needed for patients to return to functional activities and causes side effects including flexion contractors, articular cartilage damage and muscle atrophy.

The evolution of clinical knowledge causes progressive manufacturers to continually change their products to meet the needs of the medical community. If the rehabilitation protocol calls for passive ROM, the isokinetic dynamometer must accommodate. If the protocol calls for reactive eccentric exercise, the isokinetic dynamometer must accommodate. Likewise, clinicians must continually update and increase their knowledge of the tools at their disposal — and isokinetics in particular — in order to provide the most effective and efficient treatment.

## THE ISOKINETIC REVOLUTION

Isokinematic (constant angular velocity) devices have been used to assess muscle function for over 60 years<sup>1</sup>, but it was the concept of isokinetic exercise introduced into the scientific literature in 1967 by Hislop and Perrine<sup>2</sup>, that prompted a revolution in exercise training and rehabilitation.

In brief, isokinetic devices allow individuals to exert as much force and angular movement as wanted, but restrict speed from exceeding a maximum, predetermined velocity. Since the inception of isokinetics, this form of testing and exercise has become increasingly popular in clinical, athletic, and research settings. The ability of a dynamometer to

permit precise torque measurement with minimal torque artifact, created by the application of resistive forces by the dynamometer during the control of lever arm angular velocity, is of particular importance to researchers. Over the past decade, various manufacturers have developed units to measure force and torque output, as well as, acceleration, deceleration, torque at specific angles and other variables of importance. A typical finding using such devices has established that concentric training (of the rotator cuff) increases both concentric and eccentric strength while eccentric training increases eccentric strength only<sup>3</sup>. This and many new research articles have pointed to isokinetic systems as not only research and testing devices but, if properly utilized, clinical aids that can measurably speed up and enhance the rehabilitation process.

## ISOKINETICS AND THE MODERN PHYSICAL THERAPY PROGRAM

Given the current climate in which managed care now plays a significant role, clinicians would be wise to integrate various activities, including isokinetics, into their repertoire of rehabilitation techniques. Today's HMO's and PPO's demand objective documentation and reward clinicians who can provide both efficient and expedient physical therapy. In the words of one HMO case manager, "If a patient has had a quad deficiency, we pay to fix the quad, not teach them how to jump. We want clinics that can define problems, create fast treatment plans and prove the outcome." The clinician's role has not changed. As always, the clinician's role is to return the patient to activity as quickly and safely as possible. What has changed is that clinicians must now use as many resources as possible to ensure and speed up this process. In other words, it is no longer feasible to rehabilitate a patient by performing only open chain or closed chain activities or through only manual strengthening or only strengthening with the aid of a machine. *Clinicians must use the proper modality at the right time, in the right place and for the right reason.* Following such reasoning, the usefulness of integrating isokinetics into the standard physical therapy program should be readily apparent for isokinetic testing and exercise not only decreases the time a patient spends in therapy, it also provides clinicians with objective data on when to safely progress the patient to increased physical and/or functional demands.

## WHAT DOES IT ALL MEAN?

Since its inception in the late 1960's, isokinetic testing and exercise has become increasingly popular in the world of physical rehabilitation. With the current advances in technology, research, and protocols, patients are now able to return to activity sooner than in the past. Isokinetic dynamometers should be used as adjuncts to the therapist. They by no means replace clinical skills, rather, they should be used to enhance the clinician's abilities. They allow the clinician to palpate the joint while it is passively

or actively moving throughout the ROM and allow the patient to enjoy the benefits of various physical therapy techniques (PNF contract-relax, plyometrics, and/or neuromuscular control techniques,) in a safe and stable position, while working on early proprioceptive training for the muscles, joints, ligaments, and capsular structures. As noted by Dr. Noyes in late 1993, "Clinicians must resist being drawn into rehabilitation programs which do not rely on objective data." Isokinetic dynamometers today have been proven by research to be reliable in their data collection. Various studies have correlated isokinetics with functional testing<sup>4</sup>. Additional research and published literature has demonstrated that the combination of isokinetics, isotonics, and a sound home program decreases the number of complications experienced both one year and five years' post surgically, as compared with isotonics and a home program or a home program alone<sup>5</sup>.

With the combined advances in rehabilitation, surgical procedures, technology and research, and considering the HMO's which now largely decide the reimbursement climate, today's clinicians must treat more patients in the same number of hours per day. Given this fact, it is no longer feasible or desirable to use only one foundation of rehabilitation. It is no longer a world of open or closed chain, electrical or just simple modalities, hands-on or machine driven strengthening. Clinicians must utilize everything at their disposal to ensure that the patient returns to activity safely and efficiently. Isokinetic dynamometers are an integral part of the rehabilitation process. As long as the clinician utilizes the isokinetic unit as an adjunct to, not a replacement for, their clinical skills, patients will progress through physical therapy at a much faster rate.

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# WHAT'S RIGHT WITH ISOKINETICS?

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*"Isokinetics does not correlate to function."*

*"Isokinetic testing may be harmful to the joint because of shear forces."*

*"I use manual muscle testing to assess muscular strength."*

*"Isokinetic testing takes too much time"*

*"Isokinetic data is not useful."*

*"It costs too much."*

**These are just a few comments I have heard recently from clinicians expressing why the clinical usage of isokinetics is decreasing. There appears to be a propagating trend against the use of isokinetics. In my opinion, this is ill-founded, ill-advised, and in most cases inaccurate and objectionable. Allow me to explain:**

For those who feel isokinetics is not functional or does not correlate to function, there are numerous published, peer-reviewed, research articles<sup>(1-6)</sup> that have documented a strong and/or positive correlation between specific isokinetic parameters, such as quadriceps peak torque and functional testing. Recently, Wilk et al<sup>(6)</sup> reported a positive correlation between isokinetic quadriceps peak torque and functional testing in anterior cruciate ligament reconstructed patients. Additionally, the authors noted a strong correlation between the ability of the individual to accelerate and decelerate the limb, functional testing and the patient's subjective (perceived) level of function.<sup>(6)</sup> Granted, sitting on an isokinetic device and kicking the leg from knee flexion to extension could never be misconstrued as a functional exercise (unless you kick a ball or people for a living), but it appears that the ability to do so is a necessary ability which can be built on or expanded from with other rehabilitative techniques. If we are to rehabilitate a baseball pitcher from a shoulder injury, we would not begin with functional exercise, such as the throwing motion with exercise tubing or even tossing a ball. Rather, we would gradually increase the intensity, effort, and exercise specificity as the athlete improves. Function is the special duty or action required of a person as in an occupation or role.<sup>(7)</sup> Thus, we initiate functional exercises or drills only when the patient has reached an appropriate level to perform these tasks and control the forces they impart. Isokinetic testing can accurately tell us when a person has reached an appropriate level regarding their muscle strength, power and endurance to initiate "functional activities" rehabilitatively. Today's isokinetic test should not be thought of as merely a strength test, but rather

a test that documents muscular performance. The inherent strength in an isokinetic test is that it is safe, objective, reliable, and does not allow substitution.

For those who are concerned about open kinetic chain exercise that produces high joint shear forces, there are two studies<sup>(8,9)</sup> that have recently shown greater tibiofemoral shear force during closed kinetic chain (CKC) exercise when compared to open kinetic chain (OKC) knee extension. During CKC exercise, such as the squat, there is a significant posterior tibia on femur shear force (PCL stress) which is greater than the shear force produced during OKC knee extension. During OKC knee extension there is a posterior shear force produced from 100° to 60° of knee flexion then an anterior shear force (ACL stress from ≈ 60 to 0° of knee flexion. Wilk and Andrews<sup>(10)</sup> have shown that the greatest amount of tibial displacement occurs between 30 and 0° of knee flexion during isokinetic exercise. The slower the isokinetic angular velocity (60°/sec) the greater the tibial displacement in comparison to higher speeds (180, 300°/sec.) Therefore, if the clinician is concerned about stress applied to the ACL or the ACL graft, then the test should be limited to higher speeds (180°/sec or greater) and/or motion limited from 90 to 30° of active knee extension. Additionally, Isokinetic resistance is accommodating and thus is an efficient and safe form of testing.

*"Who needs isokinetic testing? Just use manual muscle testing to assess muscular strength."*

Manual muscle testing (MMT) was first described by Dr. Robert Lovett in 1912 for application to neurologically involved patients.<sup>(11)</sup> Today, the two most popular version of MMT have been developed by Kendall et al and Daniels et al. Although these MMT techniques are commonly utilized by clinicians, numerous authors have reported inherent enigmas with MMT: The grading technique appears empirical<sup>(12,13,14)</sup> poor inter-rater reliability<sup>(12)</sup>, relatively subjective test method<sup>(15)</sup>, relatively subjective test method<sup>(15)</sup>, and inconsistencies in test application and grading.<sup>(16,17,18)</sup> Wilk et al<sup>(19)</sup> have demonstrated isokinetic knee extension deficits ranging from 23 to 31% in subjects who exhibited a "normal" MMT score bilaterally. Ellenbecker et al have reported similar findings with shoulder patients.<sup>(20)</sup> Thus, it appears that a 25 to 30% isokinetic muscular strength deficit must exist before the clinician can detect the deficiency with MMT techniques. Therefore, the face validity of the MMT for the orthopaedic and sports medicine patient may not be acceptable.<sup>\*(17,18)</sup>

*"Isokinetic testing takes too much time, and the data is not at all useful."*

The average bilateral three speed isokinetic knee test takes approximately 15 minutes from start to finish. Shoulder testing (ER/IR and abd/adduction; i.e., 2 planes) at three speeds takes approximately 30 minutes. Because it is the only way of truly objectively documenting muscular performance, it is time well spent. Modern isokinetic systems render a tremendous amount of data, which at times appears overwhelming. There are several articles and chapters written which attempt to consolidate, explain, and present clinically useful data and interpretation parameters.<sup>(21,22,23)</sup> I recommend interpreting the isokinetic data functionally, using parameters such as acceleration, deceleration, reciprocal innervation time, etc, along with the torque measurements.

*"Isokinetics costs too much."*

For those who may feel this is a viable basis for isokinetic neglect, I hope this article documents the cost effectiveness. I feel it's an investment in your practice. More importantly, it's an investment in patients that enhances the objectivity of clinical effectiveness. It allows the clinician to document the need for skilled physical therapy, describe progress in detail related to performance, and qualify outcomes. It allows the clinician greater ability to accurately manage patients and appropriately determine levels of outcome. This should assist in documentation and reimbursement with third party payers. Today's insurance payers are placing greater pressure on the physician and clinician to discharge patients to function sooner than ever before, thus the clinician must document progress, or current status, more objectively than ever; isokinetics renders these results.

Isokinetics possesses inherent safety in its clinical application because of the accommodating resistance which is employed. Isokinetics is a highly effective method of muscle loading, and its utilization enhances and accelerates patient's outcome when appropriately applied. Timm has documented that patients recovering from knee surgery have an improved level of function outcomes when isokinetics are utilized as a part of their rehabilitation program.<sup>(24)</sup> The efficiency of isokinetic loading allows the patient to make musculoskeletal and neurophysiologic gains more rapidly than with any other form of muscle loading.

The future of isokinetics is bright! Isokinetics does not merely test strength but rather renders information regarding muscular performance and neurophysiologic parameters, such as acceleration, deceleration, and joint position sense.<sup>(6)</sup> Refinement and proper interpretation of these new parameters should be more closely related to "function", and will assist in determining causes of functional deficits as opposed to just confirming orthopaedic problems. Never before has getting patients better faster been more significant than it is today. Isokinetics can assist in this process.

Hence, Isokinetic should be a major component of your everyday clinical practice. The challenge is to communicate to other clinicians, administrators, insurance payers,

and patients the tremendous benefits of isokinetics.

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# THE NEED FOR CRITICAL THINKING IN REHABILITATION

George J. Davies

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## INTRODUCTION

There is an increasing emphasis on the use of closed kinetic chain exercises in the testing and rehabilitation of many patients with various pathologies. Therefore, the purpose of this article is to provide the rationale, and need for the integration of open and closed kinetic chain exercises and their application to testing and rehabilitation.....

## RESEARCH VERSUS EMPIRICALLY BASED CLINICAL EXPERIENCES

With respect to CKC exercise, we see a proliferation of "cults" and camps which advocate that clinicians should only use closed kinetic chain rehabilitation exercises in rehabilitation of certain pathologies. Yet, once again, there is a sparsity of literature to document the efficacy of this utilization. Many continuing education courses capitalize on this concept, but without published documentation. Several articles are frequently referenced as the basis of closed kinetic chain rehabilitation and its success; however, these studies were not prospective, randomized, experimental studies and they did not have control groups as a basis for comparison.

Another example of jumping on the bandwagon and demonstrating trendy treatments in rehabilitation is where we extrapolate what we have been doing with the lower extremity and assume that it will automatically apply to the upper extremity as well. The example is the application of CKC exercises and plyometrics (17, 22, 24, 34, 76, 83, 86). I am unaware of much research that documents the effectiveness of using plyometrics in the upper extremities. There are certainly many empirically based examples (10, 11, 35, 69), yet limited research. As a matter of fact, my colleagues and I have recently completed a controlled experimental study demonstrating that using plyometrics for the upper extremity for isolated training does not increase concentric or eccentric isokinetic strength of the rotator cuff muscles, nor does it improve functional throwing tests or softball throw for distance (43.) However, this is certainly one of the trendy things being advocated in the recent literature for upper extremity training.

So what do we do? As we all know, much of rehabilitation still remains an "art", but it is everyone's responsibility to provide the art with a scientific foundation. Admittedly, the art of clinical practice will always be there, and this oftentimes distinguishes the outstanding clinician (master) from the average clinician (novice), so we must respect that. We

can hope that those who do practice the art of rehabilitation at an outstanding level will also try to cross over and provide some scientific documentation along with outcome studies. The practitioner who remains exclusively with the art and "press-and-guess" techniques and does not make the effort to advance the science along with the art is the person whom I think we all need to be leery of.....

Obviously, the best solution to apply critical thinking in rehabilitation is to integrate basic research, clinical research, empirically based clinical experiences, and outcome studies. When all these are integrated, they will probably provide the optimum applications of clinical decision making.

## SPECIFIC REHABILITATION PROTOCOLS

Oftentimes, presentations and articles about rehabilitation are very general without specific details and patient outcomes. Many speakers and authors comment that there is no "cookbook" for the rehabilitation program. I disagree. I think that too often we cop out with the excuse that we individualize our treatment programs predicated on the specific requirements of the patient, and each patient is unique and different. Well, of course, each patient is unique and different. However, if we treat every patient differently and individualize each and every program, how are we going to conduct follow-up outcome studies on the results of our treatments? I think very detailed rehabilitation protocols need to be developed and followed in the rehabilitation of the patient.

This is not to say that the clinician does not have the flexibility to tailor and individualize the program to the patient if particular needs must be met or goals must be modified. What the detailed rehabilitation protocols do provide is consistency in treatments with particular pathologies and surgeries. Consequently, this allows for the pooling of research data on the patients to determine treatment outcomes. If each surgeon or clinician conducts the rehab program his or her own way (which inevitably will be different), then follow-up research data will not be valid. It is only through consistency in rehabilitation protocols and testing that we can develop reliable and valid rehabilitation protocols to demonstrate treatment efficacy and outcome studies. Recent articles and editorials support this concept, which I have advocated for the last 20 years (54, 74.).....

## INTEGRATION OF OPEN AND CLOSED KINETIC CHAIN EXERCISES AND THEIR APPLICATION TO TESTING AND REHABILITATION

### Open Kinetic Chain

A common definition used to describe an open kinetic chain is a situation in which the distal segment terminates free in space. Davies (16) defined the open kinetic chain as a rotary stress pattern with the following characteristics, using the knee as a model illustrating a knee flexion to extension motion:

- The pattern occurs in an isolated joint movement.
- There is one axis, which is relatively stable (knee).
- One part of the extremity that forms the joint is stabilized (thigh), and one part of the extremity is mobile (shin).
- The motion of the moving part of the extremity occurs in the sagittal plane for the knee joint (relative to the patient).

### Closed Kinetic (Segmental) Chain

A common definition of a closed kinetic chain is a situation in which the distal segment is fixed to an object (either moving or fixed). Davies (16) described the closed kinetic chain as a linear stress pattern, using a model the knee performing a supine leg press exercise with the following characteristics:

- The pattern occurs with multiple joint movements (hip and knee).
- The primary axis (of the specific joint being rehabilitated, in this case the knee) is translatable as well, as there are several joint axes.
- Both components of the extremity (proximal and distal) that form the joint are simultaneously moving.
- In this example of a supine leg press, the motion mostly occurs in the transverse plane for the knee (relative to the patient).

Interestingly, many individuals indicate that CKC exercises are functional and therefore should be the only type of exercise used for certain types of pathologies. Yet, when we really look at function, such as ambulation, isn't function really OKC (swing phase) and CKC (stance phase) really an integration of the two modes of exercise? Many other functional activities are really a combination of OKC, CKS, acceleration, deceleration, and concentric, eccentric and isometric muscle contractions and are not really just one mode of muscle contraction or exercise.....

### Open Kinetic Chain Testing

As with many things in rehabilitation, the pendulum swings from the popularity of one thing to the next. At the time this article was written, isokinetics was out and isokinetics "bashing" was in. Unfortunately, many clinicians have thrown the baby out with the bathwater! We readily jump on the bandwagon of something that is not well documented in prospective randomized research studies (CKC rehabilitation) and abandon something that has been used for over 25 years with over 2,000 published articles (OKC isokinetic exercises.) Why?

Certainly there are many limitations of performing OKC isokinetic testing; however, we need to recognize the limitations and then utilize the valuable information that is available from the testing.....

I would like to comment on some of the limitations that have been identified. For example, with knee testing, OKC testing can cause anterior translation of the tibia. However, this only occurs with a distally placed pad and at slower speeds. Therefore, we need to recognize the limitations of anything we do in rehabilitation and modify the procedure accordingly. Thus, concerning the example, we could use a proximally placed pad (90) and test and or rehabilitate the patient's knee at faster functional angular velocities. Oh yes, we can replicate some functional angular velocities with OKC testing and ambulation (93.) Wow, specificity of rehabilitation!

We also understand the biomechanics of the knee joint through the range of motion; consequently, we can limit the range of motion (ROM) of the knee joint from approximately 100° as the starting position to approximately 30°. Therefore, working in the appropriate ROM that protects stresses on the anterior cruciate ligament will guard the ligament from undue stresses.

It is not the equipment (whether it is an NK table, an ankle weight, a Nautilus machine, or an isokinetic device) that potentially can harm the patient; it is the clinician using the equipment. Use it right and you will not stretch out an ACL reconstruction!.....

If the ACL is stretched, the cause is not the equipment but rather the clinician who uses the equipment incorrectly and is not familiar with the proper uses, published literature, and limitations of the equipment.

I also want to address one other limitation of OKC testing. Many CKC proponents indicate that since their patients do not sit and flex and extend their knee, therefore that type of testing or rehabilitation is not functional. Although there is some controversy in the literature, the following studies do in fact show a correlation between OKC and CKC testing (5, 21, 25, 26, 75, 78, 84, 85, 89).

My philosophy is that we should do both forms of testing and consider the limitations and merits of each. I look at the testing sequence as being a series of progressive activities that go from safe, controlled, protected activities to activities where there is less control and more stress imposed on the injured area.....

## OKC AND CKC REHABILITATION AND TRAINING

OKC exercises have been used in patient rehabilitation for many years with documented results (19, 31, 55, 94). As a matter of fact, over 2,000 articles have been published on the use of OKC isokinetics alone (19). When we also consider all the articles that have incorporated OKC progressive resistive exercises (weight training), it probably includes hundreds more (19, 31, 55, 94).

All treatments have their risks and rewards, advantages and disadvantages. There is usually no one best treatment; rather, treatments should be incorporated into an "integrated

rehabilitation program." The concept of an exercise progression continuum was published over a decade ago. This concept presented a progression of exercises that could be incorporated into a rehabilitation program. The emphasis in the exercise progression continuum was to use an integrated approach in the rehabilitation of patients with various pathologies. Following is the Davies Exercise Progression Continuum; all exercises are to be done in OKC and CKC as soft tissue healing, signs, and symptoms allow, and, of course, if there are no contraindications (16).

- Submaximal multiple-angle isometrics
- Maximal multiple-angle isometrics
- Submaximal short arc exercises (isotonics, isokinetics, plyometrics)
- Maximal short arc exercises (isotonics, isokinetics, plyometrics)
- Submaximal full-ROM exercises (isotonics, isokinetics, plyometrics, functional exercises) (unless contraindicated)
- Maximal full-ROM exercises (isotonics, isokinetics, plyometrics, functional exercises) (unless contraindicated)

There have been many trends in orthopedics and sports rehabilitation over the years. One current trend is to not use OKC isokinetics because it will hurt the patient or worsen the injury. Admittedly, any modality when used incorrectly has the potential to hurt a patient. However, is the OKC isokinetics to blame, or is it the clinician using the equipment? If a patient is burned with a hot pack, is it the fault of the hot pack or of the clinician using the modality? Has surgery ever hurt a patient? Do we stop doing all surgeries? As Hughston (47) has stated, there is no orthopedic condition that cannot be made worse by surgery.

Consequently, we have to keep an open mind and critically evaluate the literature regarding the effectiveness of OKC exercises that have been demonstrated over many years. Over 20 years of empirically based and scientifically documented (19, 85) use of the integrated approach (OKC and CKC) has produced successful results. There is certainly a need for more research to demonstrate the integration of the basic sciences, the clinical sciences, clinical application, and outcome studies documenting the most effective way to provide the optimum rehabilitation.

Kannus et al. (53) stated that knees (patients with partial ACL injuries) with previous ligamentous injury are in the greatest need of specific high-speed thigh muscle exercises. The new isokinetic dynamometers offer an excellent opportunity for such training. The reason is due to specificity deficits; power deficits are significantly greater in high speeds of isokinetic movements. But the supposed detrimental effects of one type of therapy do not necessarily prove the alternative form (71).....

#### Closed Kinetic Chain Rehabilitation

The interdependence of the CKC means that a change in position or movement pattern of one segment must be accompanied by changes or compensation in the movement

patterns of positions of adjacent segments. Therefore, in a closed kinetic chain, motion at one joint will produce motion at all of the other joints in the system in a predictable manner.

However, with an injury/pathology/dysfunction that has pain, swelling, limited ROM, limited flexibility, or muscle weakness, how can the CKC exercises occur in a predictable manner due to the restrictions? Therefore, compensations must occur, interfering with the

- predictable pattern of movement,
- normal joint arthrokinematics,
- normal joint osteokinematics,
- normal muscle contractions, resulting in compensatory muscle recruitment patterns, and
- normal motor learning (neurophysiological patterning), therefore reinforcing an abnormal motor pattern

Consequently, if only CKC exercises are performed, then the proximal and distal musculature may mask any deficits and the involved area may not be totally rehabilitated. The weak link of the kinetic chain must be tested and identified in order for the clinician to rehabilitate it and to establish discharge criteria (26, 36, 63). If we only do CKC total lower extremity exercises, then the isolated specific deficits may never be corrected.

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# PHASES OF REHABILITATION

## PHASE I

### HEALING CONSTRAINTS AND PROVING NEED

Gentle Range of Motion exercise in the passive mode is recommended for nearly every pathology... ligament, cartilage, fracture, etc. to help facilitate the healing process by increasing the vascular supply to the injured joint and pumping out the waste products from the trauma to the joint.

. Isometric testing can be integrated at virtually any time - post-injury and/or pre- or post-surgery to document the deficit in the injured joint vs. the uninjured and set baseline data.

## PHASE II

### CONTROLLING JOINT EFFUSION/INFLAMMATION

Utilizing the passive mode interfaced with ice, neuromuscular electrical stimulation (NMES), or any other joint effusion controlling modalities, allows motion with reduction in effusion and allows the muscles and limbs surrounding the joint to work as a muscular pump to move blood, lymph and other waste products out of the joint.

Only the Biodex Multi-Joint Systems have the manual control necessary to begin and advance the patient at the earliest stages post-injury or post-surgery - speed capabilities to move the joint as slow as 2\_/sec and force capabilities as low as .5 ft-lbs.

## PHASE III

### RESTORING RANGE OF MOTION

The manual control of the Biodex System allows Range of Motion (ROM) to be restored by turning the ROM selector dials to increase the range to that of the normal/uninjured joint, with pauses to initiate a static stretch at the end ROM.

Only Biodex Multi-Joint Systems allow clinicians to utilize contract/relax exercise in the passive mode to use the antagonistic contractions to assist in restoring ROM.

## PHASE IV

### RESTORING STRENGTH AND PROVING PROGRESS

Passive mode allows any contraction type or contraction sequence to be performed. First, utilizing a manual style - submax resistive double eccentric contractions, with the torque limits at very low levels to perform safe resistive exercise, re-educating the patient on how to contract their muscles at the appropriate submax level. The patient can be progressed to active assistive contractions in the passive mode where they can concentrically contract in pain-free spots in the ROM and produce no force in the painful spots.

The patient receives the benefit of the full ROM exercise without the hindrance of recreating the symptoms by producing force in painful arches of motion.

The patient can exercise in the concentric/concentric isotonic mode with isotonic resistance set as low as .5 lbs. and allowed to safely accelerate and decelerate a submax load and progress to more challenging loads and functional speeds - all without placing damaging impact loads on the joint. The isokinetic mode allows impact-free isokinetic exercise, which allows the joint and surrounding musculature to be submax and max loaded in the safest and most efficient manner possible at the largest variety of speeds with variable speeds for the antagonistic or agonist muscles.

## PHASE V

### RESTORING FUNCTION

Isokinetic concentric/concentric muscle loading allows the muscles to be exercised in a manner that maximizes safety and approximates function. With the Biodex Multi-Joint System this is performed impact-free and in functional positions with velocities that approach functional speeds.

The impact- and inertia-free isotonic mode allows muscles to contract exactly as they would performing functional activities, allowing the movements to occur at functional speeds in functional positions.

## PHASE VI

### DISCHARGE CRITERIA

Only Biodex allows five different modes for testing, allows the individual patient's test results to be compared to normative data, and reports all information in ready-to-mail reports. In addition, only Biodex allows the patient's ability to accelerate to a predetermined speed and deceleration from that speed to be evaluated. Acceleration to a preset speed of 300\_/sec or faster has been demonstrated to show a positive correlation to functional tests or tests of the patient's ability to function.



EXCERPTED FROM:

# OPEN KINETIC CHAIN ASSESSMENT AND REHABILITATION

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## DEFINITION

An operational definition of an OKC test or exercise, within the limitations of this article, is when the distal end of the extremity is free and not fixed to an object...

## RATIONALE AND NEED FOR OKC REHABILITATION

Although the purpose of this article is to describe the rationale and need for OKC rehabilitation, we think a few comments are necessary regarding ... CKC exercises. Many articles have described the rationale to use CKC exercises, particularly when rehabilitating patients with anterior cruciate ligament (ACL) reconstructions. However, Crandall et al. performed a meta-analysis of 1,167 articles published on the treatment of patients with anterior cruciate ligament injuries between 1966 and 1993. Only 5 articles (and 3 of these articles included data on the same patients) met the criteria for a meta-analysis of prospective, randomized, controlled, experimental clinical trials. Consequently many of the articles that are commonly referred to as "definitive treatment articles" are simply descriptive studies. The one who defines the rules of the game can always be successful. Therefore, many individuals and articles describe the benefits of using CKC exercises in rehabilitation, but few scientifically based, prospective, randomized, controlled, experimental clinical trials document the efficacy of CKC exercises.

Even if supposedly negative effects of one type of exercise (OKC) exist, that existence does not necessarily prove that the opposite type of exercise works. Consequently, many of the articles "driving the reasons" to use only CKC are founded more in myths, empirical observations, good science which has not proven the efficacy, bad science which has tried to prove the efficacy, and descriptive studies.

## RATIONALE FOR OKC ASSESSMENT

The reasons to incorporate OKC exercises in both assessment and rehabilitation are as follows:

1. It is necessary to perform isolated testing of specific muscle groups usually affected by certain pathological changes. If one never measures the component parts of the kinetic chain, then the weak link will never be identified or adequately rehabilitated. The kinetic chain is only as weak as the weakest link.
2. Muscle groups away from the specific site of injury must be assessed to determine *other* associated (e.g. disuse, pre-existing) weaknesses.
3. Closed kinetic chain or total extremity testing may not demonstrate the true weakness that exists; oftentimes proximal and distal muscles compensate for weak areas.
4. Performing OKC testing allows the clinician to have significant control. In other words, the examiner controls the range of motion (ROM), speeds, translational stresses (by shin pad placement), varus-valgus forces, rotational forces, etc. When one begins CKC exercises, control of the aforementioned variables increases, thereby increasing the potential risk of injury to the patient.
5. Although most patients do not sit flexing and extending their knees in an OKC pattern when they function, numerous studies demonstrate a correlation between OKC testing and CKC functional performance (based on a variety of functional assessment tests).
6. When a patient has an injury or dysfunction related to pain, reflex inhibition, decreased ROM, or weakness, then abnormal movement patterns often result and create abnormal motor learning. Isolated OKC training can work within the limitations to normalize the motor pattern.
7. Efficacy of rehabilitation with OKC exercises.

The primary purpose of performing OKC assessment is the need to do isolated testing of the specific muscle groups of a pathological joint. Although the muscles do not work in an isolated fashion, we will never identify the "weak link" in a kinetic chain unless specific isolated OKC testing is performed. If we do not test (isolated OKC), we will know if and when a deficit exists. Furthermore, on serial retesting we will not know how the patient is progressing and if and when the patient meets the parameters for discharge. Examples of the importance of performing isolated testing of the kinetic chain to identify specific dysfunctions have been offered by several authors including Nicholas et al. and Gleim et al....

It is important to note that the only way we know there are weakness in muscle groups distant to the site of injury is because isolated OKC testing was performed. Furthermore, identification of specific muscle weakness at the injury site also can only be determined by isolated OKC testing. Another example illustrating the need to do isolated testing is demonstrated in the recent work by Davies who performed CKC computerized isokinetic testing of patients with various knee injuries and also performed bilateral comparison data analysis. Dynamic CKC testing requiring a linear motion with force production being measured in pounds at slow (10 inches/sec), medium (20 inches/sec) and fast velocities was done on a Linea computerized CKC isokinetic dynamometer system... The same patients were also tested on a ... OKC computerized isokinetic dynamometer...

and the data were again calculated as a bilateral analysis. Isolated joint testing was performed as a rotational force and torque values were recorded at slow (60 degrees/sec), medium (180 degrees/sec), and fast (300 degrees/sec) angular velocities. The results of the test demonstrate that more significant deficits exist in patients with OKC isolated joint and muscle testing than in patients with CKC multiple joint and muscle testing. When testing multiple groups and developing a summative composite score of their forces, apparently the proximal and distal muscles compensate for weak muscles and tend to demonstrate less of a deficit than what really exists in the area. The senior author has made this empirically based observation for years, but now, CKC testing that objectively documents and quantifies performance has supported this observation. Remember, if you do not measure a muscle's performance, you do not know if and when a deficit exists. These aforementioned research studies and examples, should certainly provide justification regarding the need for OKC testing.

Another primary reason for performing OKC testing is because of the clinical control afforded. When testing, the examiner controls ROM, speeds, translational stresses (by shin pad placement), varus and valgus stresses, rotational forces, etc. However, when one begins CKC testing, control of the aforementioned variables decreases, thereby increasing the potential risk to the patient.

Often the example is used that performing OKC testing on a patient who had an ACL reconstruction can stretch or injure the graft. This is based more on good science being poorly applied to the clinical setting. If the graft were to actually be stretched during OKC testing, is it really the OKC test or is it the clinician doing an inappropriate test or testing at an inappropriate time? Patients have been burned with a hot pack. However, if a patient gets burned, is it really the hot pack's fault, or is it the clinician using the hot pack inappropriately.

When testing or rehabilitating a patient after an ACL reconstruction, the following guidelines should be used to prevent injury:

1. Know the type of surgery (e.g. autograft, allograft)
2. Know the fixation
3. Know the graft status (KT1000)
4. Have established testing guidelines for particular pathological conditions (exceptions, however, are always made)
5. Respect soft tissue healing times (based on clinical protocols)
6. Proximally placed pad
7. Limit ROM (avoid 30 degrees to 0 degrees)
8. Use faster velocities

### **OKC CORRELATION TO CKC FUNCTIONAL PERFORMANCE**

Another reason to perform OKC testing is, once again, because of clinical control and the correlation of OKC testing to CKC functional performance. Although patients do not function regularly sitting in a seat flexing and extending their knees... numerous studies do demonstrate a positive correlation between OKC testing and functional performance...

Isokinetic assessment allows the clinician the ability to objectively assess muscular performance in a way that is both safe and reliable. Isokinetic testing affords the clinician objective criteria and provides reproducible data to assess and monitor a patient's status. Isokinetic testing has been demonstrated to be reliable and valid...

### **ASSESSMENT AS THE SCIENTIFIC AND CLINICAL RATIONALE FOR THE DESIGN OF OKC REHABILITATION PROGRAMS**

Many types of exercise programs are currently in widespread use for rehabilitating patients. Of course, this is only one part of a total rehabilitation program. These programs vary from isometric, isotonic-concentric, isotonic-eccentric, isotonic-variable resistance, isokinetic-concentric, isokinetic-eccentric, biokinetic, plyometrics, accelerative-kinetic, and variations of these basic programs. Besides these specific modes of exercise, many programs reportedly increase muscle performance.

### **THERAPEUTIC EXERCISE PROGRAM CONSIDERATIONS**

After a comprehensive subjective and objective examination is performed to generate a data base, the rehabilitation program must be predicated on the examination findings. Various considerations of a total rehabilitation program should include treatment techniques directed toward each of the following areas where a problem or a potential problem exists.

1. Protection of the area
2. Rest from stress but not limited function (relative stress)
3. Decreased pain
4. Decrease swelling
5. Increased joint ROM
6. Restoration of normal joint arthokinematics
7. Increased musculotendinous flexibility
8. Increased muscle slow contractile strength
9. Increased muscle fast contractile power forces
10. Increased muscle fast contractile endurance forces
11. Correction of mechanical dysfunctions
12. Use of assistive devices such as orthoses, knee appliances, and taping
13. Increased joint proprioception and kinesthesia
14. Increased functional abilities
15. Rectification of causative factors such as shoes or surfaces...

### **PATIENT PROGRESSION CRITERIA**

The patient's progression through the exercise program is dictated by continual reassessment of the patient's subjective symptoms and objective signs...

#### **Rationale for the Use of OKC Exercises in Rehabilitation**

In an OKC movement, when the ends of an extremity or a portion of the body can move freely without causing motion of another joint, motion does not occur in a predictable fashion, whereas, in a CKC movement there is a system of joints and links constructed so motion of one link at one joint will produce motion at all other joints in the system in a predictable manner. However, when injury, pathological change or dysfunction cause pain, swelling, limited joint ROM, limited flexibility, or muscle weakness, how can the

CKC exercises occur in a predictable manner? Because of these restrictions on movement, compensations must occur interfering with the following:

- Predictable pattern of movement
- Normal joint arthokinematics
- Normal joint osteokinematics
- Normal muscle contractions, resulting in compensating muscle recruitment patterns
- Normal motor learning (neurophysiological patterning), therefore reinforcing an abnormal motor pattern

The concept of practice makes permanent, not perfect, must also be considered. For example, if a patient is throwing athlete and has a dysfunction, the primary mode of rehabilitation is not throwing. In shoulder rehabilitation =, we often use a part-whole-part-whole rehabilitation process. So we perform isolated rehabilitation and then integrate isolated regained functions back into overall functional performance.

Why then, when there is a lower extremity problem, do we just do CKC (whole) rehabilitation? As a part of the entire rehabilitation program it is important to use isolated OKC exercises as a part of the entire rehabilitation program. Although total limb movements may be considered more functional, isolated joint movements have great merit in cases where the patient cannot overcome an abnormal motor pattern that involves substitution of the wrong muscles at the wrong time (example, using hip extensors and the hamstrings to extend the knee in a CKC position).

Isolated limb movements should not be completely abandoned as a means of improving function. If normal firing patterns of muscle activity cannot be achieved through total limb training, which should include biofeedback training, then isolated joint training can be very useful. When employing isolated limb movements, proper stabilization makes it virtually impossible for the patient to substitute inappropriate muscles to complete the task. Once adequate motor control of the affected muscle is restored, functional or CKC training should be initiated...

### ISOKINETIC REHABILITATION

Unlike isotonics, isokinetics have a fixed speed with accommodating resistance. Therefore, maximal dynamic loading of the muscle is accomplished through the full ROM at a preset speed. Although several indications are similar to those offered by isotonics, isokinetics provides the clinician with a more encompassing exercise method. Various techniques can be applied to individualize an isokinetic rehabilitation program. The program must be designed around the patient's specific limitations and must avoid iatrogenically increased symptoms.

### RANGE OF MOTION

Short arc ROM can be effectively used with isokinetic training because of a 30 degree ROM physiological overflow; 15 degree overflow occurs at each end of the exercised ROM. This allows for strengthening of the muscle within the non exercised ROM. The clinical importance of this is best demonstrated with rehabilitation of a patient with a patellofemoral syndrome. Because of the increased patellar surface articulation with the femoral condyles

through the ROM of 30 to 60 degrees of knee flexion, quadriceps strengthening must be limited to avoid this ROM. By Working from full flexion to 60 and from 30 degrees to 0 degrees, this painful ROM can be avoided without compromising strength gains. This approach can also be used with patients who have undergone ACL reconstructions to avoid the end ROM 30 degrees to 0 degrees. With short arcs of motion, usually an intermediate velocity spectrum rehabilitation program (VSRP) is used.

### VELOCITY SPECTRUM REHABILITATION PROGRAM

The isokinetic training speeds are divided into 4 velocity spectrums. Based on previous studies demonstrating a 30 degree/second physiological overflow, training occurs at the end speeds and every 30 degrees/second in between. For example, the intermediate VSRP would consist of performing a set at 60 degrees per second, then at 90, 120, 150, and 180 degrees/second. This is then repeated from 180 degrees/second back down to 60 degrees/second.

The variety of speeds offered is an advantage that isokinetics has over most isotonic training. The majority of isotonic exercises are conducted at a speed of approximately 60 degrees/second. Because many functional activities occur at speed greater than 60 degrees/second, isokinetic training allows for improved training specificity...

### INTENSITY

Muscle fiber type recruitment will depend on the level of training intensity. This aspect is important in the rehabilitation of various injuries. Slow twitch muscle fiber atrophy has been demonstrated to occur with various injuries.

Selective recruitment of slow twitch fibers can be accomplished through submaximal training at less than 30% of maximum. The biofeedback controls on most isokinetic equipment allow for the clinician and patient to easily monitor the training level. Although the rehabilitation goal is for patients to perform at a maximum level, they should begin at a submaximal level and progress to maximal based on subjective and objective reassessment data. Submaximal exercise offers a variety of benefits, such as articular cartilage nourishment and mechanoreceptor stimulation, without stressing the injured structures. These can help to expedite the overall rehabilitation time. Furthermore, from a specificity standpoint, most activities of daily living (ADL) are performed at a submaximal intensity...

### ENERGY SYSTEM

Specific energy systems can be enhanced with certain isokinetic velocities. A recent study by Douris examined the effects of exercise on blood lactate and muscle fatigue. The results demonstrated that as the isokinetic training speed is increased, so is the lactate level. This suggests that effective stressing of the anaerobic energy systems (ATP-CP and lactic acid) can be accomplished using fast isokinetic velocities...

## OUTCOMES RESEARCH

There has been an interesting evolution of rehabilitation during the last several decades. We think it can best be described in the following way:

1970s Functional rehabilitation

1980s OKC assessment and rehabilitation (with emphasis on isokinetics)

1990s CKC rehabilitation

By 2000, integrated assessment and rehabilitation should include both OKC and CKC.

Recently, Bynum et al. published an article entitled “Open versus closed chain kinetic exercises after anterior cruciate ligament reconstruction: A prospective randomized study.”...

Surprisingly, Bynum et al. deduced several conclusions that were not statistically significant and probably not clinically significant either. Yet, they based their entire protocol exclusively on these findings...

Amazingly, this has been done based on fads, anecdotal information, and descriptive studies, with limited published prospective randomized experimental studies proving the efficacy. Yet, most clinicians have “thrown out the baby with the bathwater.” Over 2,000 articles have been published on OKC isokinetics and thousands more on OKC isotonic. Most clinicians ignore past successes and have jumped on the CKC bandwagon, without documentation.

In a recently published article by Synder-Mackler et al. prospective randomized clinical trials and the effects of intensive CKC rehabilitation programs and different types of electrical stimulation on patients with ACL reconstructions are described. These researchers previously demonstrated that the strength of the quadriceps femoris muscle is well correlated with the function of the knee during the stance phase of gait. In the present study following an intensive CKC rehabilitation program, a residual weakness remained in the quadriceps that produced alterations in the normal gait function of these patients. The authors concluded that CKC exercise alone does not provide adequate stimulus to the quadriceps femoris to permit more normal knee function in the stance phase of gait in most patients soon after ACL reconstruction. Synder-Mackler et al. recommend that the judicious application of OKC exercises for the quadriceps femoris muscle (with the knee in a position that does not stress the graft) improves the strength of this muscle and the functional outcome after reconstruction of the ACL...

Therefore, we strongly encourage clinicians to use an integrated approach to assessment and rehabilitation...



EXCERPTED FROM:

## THE EFFECTS OF ISOKINETIC VS. PLYOMETRIC TRAINING ON THE SHOULDER INTERNAL ROTATORS

Bryan C. Heiderscheit, PT, CSCS

Karen Palmer McLean, PhD, PT

George J. Davies, MEd, PT, SCS, ATC, CSCS

JOSPT • Volume 23 • Number 2 • February 1996

Because upper extremity plyometric exercises have also been introduced into upper extremity rehabilitation programs, there is a need to determine the effects of plyometric training of the upper extremity on various performance parameters...

### TRAINING PROGRAM

Subjects were randomly assigned to three groups: control group (N=27), isokinetic training group (N=27), and plyometric training group (N=27).

The isokinetic and plyometric groups trained two times per week for 8 weeks. This frequency allowed the needed rest period associated with plyometric training.

Both training groups performed a 3-minute submaximal warm-up...

The plyometric group trained on the Plyoback System (Functionally Integrated Technologies, Watsonville, CA) (Figure 3). The subjects stood 152.4 cm (5 ft) from the center of the trampoline and threw the weighted balls at it using a one-handed overhead throw of the dominant arm...

The isokinetic... trained using both concentric and eccentric contractions in the same bout to replace the plyometric training exercise.

The training protocol (Table 1) consisted of three sets of 10 repetitions during weeks one and two at concentric and eccentric speeds of 240°/sec and 180°/sec, respectively. These speeds were chosen to as closely replicate a functional throw...

### RESULTS

Significant concentric gains were made in the isokinetic group at speeds of 120°/sec ( $p<.05$ ) and 240°/sec ( $p<.01$ ) (Table 3). The isokinetic group also exhibited significant eccentric gains at 60°/sec ( $p<.01$ ), 120°/sec ( $p<.01$ ), and 240°/sec ( $p<.0001$ )...

The results of this study support previous findings by showing concentric increases at 120°/sec and 240°/sec but not at 60°/sec, which is outside the range of physiological overflow.

Eccentrically, subjects trained at speeds of 90°/sec and 180°/sec; however, significant increases were noted at all three testing speeds. Previous work suggests that physiological overflow occurs in the eccentric velocity spectrum...

The significant improvements in eccentric and concentric power output at various speeds for the isokinetic group were to be expected... Previous studies have demonstrated the effectiveness of isokinetic training in increasing power output. The fact that the plyometric group did not show significant increases at any of the testing speeds was of greater interest. Several possibilities exist to explain this finding. First, the training program for the isokinetic group was designed for optimal power gains. Training parameters have already been established in previous studies. For example, Davies et al showed that 10 repetitions were appropriate to achieve optimal power gains...

Secondly, it was difficult to control the throwing motions used by subjects in the plyometric group...

Finally, plyometrics need to be performed at maximal intensity at all times for optimal gains...

### CONCLUSION

Isokinetic training resulted in a significant increase in concentric and eccentric power after 8 weeks of training the shoulder internal rotators. These results support that of previous research, indicating the effectiveness of isokinetics for improving power output. Plyometric training was not effective for increasing power output.

EXCERPTED FROM:

## STRENGTH OF THE QUADRICEPS FEMORIS MUSCLE AND FUNCTIONAL RECOVERY AFTER THE RECONSTRUCTION OF THE ANTERIOR CRUCIATE LIGAMENT

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Anthony DeLitto PT, PH.D Pittsburgh, Pennsylvania

Sherri L. Bailey MSPT, St. Louis, Missouri

Susan W. Siralka PT, Germantown, Tennessee

[The Journal of Bone and Joint Surgery • Vol. 77-A • No. 8 • August 1995]

Rehabilitation of the quadriceps femoris muscle after an operation on the anterior cruciate ligament was de-emphasized in the late 1970's and early 1980's because of concerns related to the possible deleterious effects on the graft of excessive anterior translation forces during exercise. Currently, intensive, early intervention is routine and so-called closed-kinetic-chain (weight bearing and multi-joint) exercises are begun in the early postoperative phase. Recent reports regarding the outcome of reconstruction of the anterior cruciate ligament have continued to document persistent weakness of the quadriceps femoris despite advances in the treatment of injuries of the anterior cruciate ligament...

Weakness of the quadriceps femoris after a reconstruction of the anterior cruciate ligament has been attributed to patellofemoral pain that prevents the patient from exercising properly, deformity of the joint, lesions in the articular cartilage, poor operative timing and incorrect placement of the graft...

While the causes of incomplete recovery of the quadriceps femoris remain elusive, orthopaedic surgeons still strive to obtain full recovery after reconstruction of the anterior cruciate ligament. The persistent weakness of the quadriceps femoris that has been seen in many patients has led to questions concerning whether closed-kinetic-chain exercise, during which several muscles (such as the gastrocnemius, quadriceps femoris, hamstrings and gluteals) are active at once, provides an adequate training stimulus to the quadriceps femoris. We demonstrated that judiciously administered regimens of electrical stimulation improve the recovery of the quadriceps femoris in the early postoperative phase (the first six weeks) after reconstruction of the anterior cruciate ligament. We also demonstrated a strong relationship between recovery of this muscle and the quality of the gait of these patients... The purpose of the present prospective, randomized clinical trial, which involved a large sample of patients from several clinical centers, was to assess the effectiveness of common regimens of electrical stimulation as an adjunct to ongoing intensive rehabilitation...

### RESULTS...

The addition of high-intensity neuromuscular electrical stimulation to an intensive postoperative training program resulted in at least 70 per cent recovery of the quadriceps by six weeks after the operation. When the regimens had not included high-intensity stimulation the recovery of the quadriceps was 51 per cent (in the group treated with low-

intensity stimulation) and 57 per cent (in the group treated with high-level volitional exercise).

### DISCUSSION...

Our results indicate that judiciously applied open-kinetic-chain exercises for the quadriceps femoris (fifteen contractions three times a week) with use of the high-intensity electrical stimulation with the knee in a protected position (65 degrees of flexion) improve recovery of the quadriceps and result in better gait patterns than when no high-intensity electrical stimulation is used. The open-kinetic-chain (high level) volitional quadriceps exercise also provided an additional training stimulus...

Patients who had been managed with high intensity electrical stimulation walked with more normal excursions of the knee joint during stance than those who had been managed with low-intensity electrical stimulation or high-level volitional exercise, presumably because of better recovery of the quadriceps femoris...

Co-contraction or co-activation of antagonistic muscles, in this case the quadriceps femoris and hamstring muscles, has a role in maintaining stability of the joint and could result in the flexed-knee gait that has been demonstrated by patients who have a weak quadriceps...

Co-contraction tends to stabilize a joint in a single position. Therefore, in an effort to counter the external flexion moment that occurs during a flexed knee stance time might be demonstrated by patients who have a weak quadriceps femoris muscle...

Rehabilitation after reconstruction of the anterior cruciate ligament continues to be guided more by myth and fad than by science...

We demonstrated previously and in the present study that the strength of the quadriceps femoris muscle is well correlated with the function of the knee during the stance phase of walking. We believe that the observed alterations in the gait of patients in the present study represent an adaptation related to weakness of the quadriceps femoris. This weakness closely predicts functional outcome. The present study confirms the finding that strength of the quadriceps femoris has a substantial impact on functional recovery and suggests that closed-kinetic-chain exercise alone does not provide an adequate stimulus to the quadriceps femoris to permit more

normal function of the knee in stance phase in most patients in the early period after reconstruction of the anterior cruciate ligament. The cost of the additional intervention is low, and the number of visits to a rehabilitation facility that are necessary may actually decrease as a result of this rehabilitation regimen. We believe that judicious application of open-kinetic-chain exercises for the quadriceps femoris muscle (with the knee in a position that does not stress the graft) with the use of high-intensity neuromuscular electrical stimulation improves the strength of this muscle and the function outcome after reconstruction of the anterior cruciate ligament.

# MULTI-MODE SYSTEM



BIODEX IS THE ONLY DEVICE THAT PROVIDES CLINICALLY PROVEN MULTIPLE MODE TRAINING AND TESTING. THIS MEANS YOU, THE BIODEX CLINICIAN, CAN TREAT PATIENTS SOONER AND RETURN THEM TO FUNCTIONAL ACTIVITIES FASTER.

**ISOKINETIC MODE**

Isokinetic Mode with impact-free acceleration - The Biodex is designed to eliminate joint trauma during acceleration and achievement of speed. This allows patients to exercise at higher, more functional speeds. The Biodex collects torque data and monitors velocity throughout the entire range of motion, even if the patient does not meet the preselected speed.

## IN REHABILITATION

The Isokinetic mode may be used at high speeds to replicate athletic performance or functional activities, or at speeds where injuries occur. Working the knee musculature near or above these speeds conditions the supported musculature and soft tissue.

The isokinetic mode may be used for bi-directional velocities e.g. During early ACL reconstruction rehabilitation, the hamstrings may be worked at low speed and the quadriceps at high speeds.

## IN TESTING

The isokinetic mode is commonly used for assessing joint performance.

The test may be to document a musculoskeletal deficiency or patient progress with a rehabilitation program.

## CONTINUOUS PASSIVE MOTION (CPM)

Passive Mode is a multi-function modality whose unique control properties allow for early intervention. The Biodex passive mode allows for the combination of muscle loading techniques for:

1. Decreasing joint effusion
2. Increasing range of motion
3. Developing strength

Passive speed can be set to as low as 2°/sec. - low enough to overcome the natural stretch reflex threshold.

Biodex torque limits can be set as low as .5 lbs. if a torque limit is exceeded during an eccentric contraction, the system stops. Once the patient's torque output drops below the pre-selected limit, movement is allowed.

This unique feature allows the clinician to work the patient at definitive prescribed submaximal force levels, while combining isometric, concentric and eccentric contractions during the early stages of joint strengthening.

# SYSTEM 3 RECURRING THEMES

## Neuromuscular Evaluation and Therapeutic Exercise



*The fastest way to identify, treat and document the physical impairments that cause functional limitations.*

A mode of operation for each phase of rehabilitation.

## ISOKINETICS

(Fixed speed, Accommodating Resistance)

- **Resistance accommodates to**
  - musculoskeletal leverage system
  - fatigue
  - pain
- **Safe**
  - resistance is equal to the force applied
  - decreased joint compressive forces as speed increases
  - produces minimal muscle soreness
- **Efficient**
  - muscle group can be loaded to its maximum capability throughout the entire range of motion
  - improves strength of bone-ligament-bone complex
  - increases muscle fiber cross-sectional area
- **Identifies physical impairments**
  - strength deficits are identified by area in range of motion and by movement speed
- **Objective assessment of need, progress and outcome**
  - testing and exercise conditions can be reproduced and documented
- **Correlates to functional activities**
- **Consistent with exercise principles**
  - progressive loading
  - specificity of exercise
    - velocity spectrum training



# THE CORRELATION BETWEEN ISOKINETIC STRENGTH MEASURES FUNCTIONAL PERFORMANCE IN AN ELDERLY POPULATION

M.H. Campbell

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Strong empirical data exists suggesting a correlation between risk of falls and functional mobility and quadriceps muscle strength in the elderly. A correlation matrix was constructed between the functional performance variables, gait speed (GS), agility (AG), balance (BAL), and stand-up time (SU) and isokinetic knee extension (KE) and flexion (KF) measures of peak torque, total work, average power (EAP, FAP), peak torque per unit body weight (EPTBW, FPTBW), and average power per unit body weight, at 60°/s, 180°/s, and 300°/s. Seventy-four subjects, 62-78 years old (34 males, 40 females) were evaluated. Results indicated a significant positive linear correlation between isokinetic performance during KF and KE and BAL, ( $p < 0.05$ ). These correlations improved as the speed increased for KE variables, for example, for EPTBW 60°/s = .384, 180°/s = .389, 300°/s = .433,  $p = .0001$ . Once again, the opposite trend was seen with KF. There was also a significant positive correlation between GS and KE across all speeds, for example, for EAP 60°/s = .300, 180°/s = .423, 300°/s = .501,  $p = .0001$ . This significant correlation also held true for KF, however, there were lower correlations at higher speeds. Correlations of AG and SU with isokinetic variables for KF and KE were low at all speeds of contraction. The positive correlations of isokinetic leg strength variables with BAL and GS offer a direct indication of the importance of resistance training of the leg musculature to reduce the risk of falls and improve mobility. The trend toward higher correlations at higher extensor speeds may indicate the need to include high velocity training in these resistance protocols.

# Why you need a multi-joint system and why that system *must* be a Biodex

By Thurman Ballard



In a managed care environment, clinicians must return patients to definable levels of function as quickly as possible.

The best way to deliver efficient and cost effective treatment, and provide quality care is to evaluate the patient, define the level of impairment, and confirm the impairment cause. This evaluation must include the objective assessment of all parameters that affect function, including the musculoskeletal and neuromuscular systems.

Once the components have been assessed, a specific target outcome such as return to ADL, work, or sport can be defined. A critical pathway or treatment plan can then be created to maximize the rehabilitation process.

Without clearly defining impairment and cause, rehabilitation is little more than a guessing game based on assumption rather than objective facts. While passive treatments (such as hot packs) may relieve symptoms, only active interventions (such as therapeutic exercise) quickly progress the patient along a treatment plan to the desired outcome.<sup>1</sup> The Biodex Multi-Joint System is the only testing and rehabilitation device exclusively designed for both assessment and treatment of the parameters that define function.

## MUSCULOSKELETAL EVALUATION AND EXERCISE

The Biodex System is designed to progress patients through the rehabilitation process in the safest, quickest, and most efficient manner possible.

Only the Biodex System provides uncompromised biomechanical positioning that increases the effectiveness of the activity and encourages proper arthokinematics. This ensures that harmful patterns of compensation do not develop when the patient is returned to function. The Passive Mode allows development of the patient's passive and active range of motion (ROM), followed by the development of strength in the isolated joints and surrounding musculature.

The basis of the strengthening component is Isokinetic Muscle Loading, the only safe method of maximally loading a dynamically contacting muscle throughout a joint's entire range of motion.

Biodex exclusive torque-based ramp allows the patient to achieve Isokinetic speed sooner in the range of motion and to maintain the speed longer. This promotes greater benefits from the accommodating resistance as well as more reliable evaluations.

## NEUROMUSCULAR ASSESSMENT AND FUNCTIONAL TRAINING

Utilizing physical, auditory and visual biofeedback to train patients to perform submaximal eccentric muscle loading at preselected resistance levels develops the neuromuscular control which necessitates restoration of normal joint arthokinematics.

**The ability to accelerate to, maintain and decelerate from the pre-selected isokinetic speed, reciprocally, is the same contraction sequence performed in functional activities. Studies have consistently found a high correlation between Biodex test scores and functional tests.**<sup>2, 3</sup> Biodex torque-based acceleration is directly comparable to the ability to produce power necessary for functional activities. The ability to decelerate (the lever arm) and re-accelerate in the opposite direction develops the dynamic joint stability necessary to maintain joint integrity during functional activity. In effect, the reciprocal contractions (changing the agonist to the antagonist and the antagonist to the agonist) train the muscles to stabilize the joints instead of the ligaments, reducing the risk of injury during dynamic activity.

The majority of *connective tissue injuries* occur at the end range of motion, during the reciprocal transition. For this reason, assessment and training of patients' capabilities is vitally important. This valuable assessment is only possible on a Biodex Multi-Joint System.

Biodex also provides the clinician with accurate, clear documentation of acceleration and deceleration to statistically demonstrate the significant correlation of the patient's functional activity.

## NEUROPHYSIOLOGICAL EVALUATION AND TRAINING

Proprioception, the complex series of afferent messages from the periphery to the Central Nervous System (CNS), and the CNS's efferent response to the muscles, is known as neuromuscular coordination. Without efficient neuromuscular coordination, the muscles will not be able to stabilize joints or even allow for the simplest of joint motions to be performed in an effective manner, hindering the patient's function.

Among the components essential to the development of neuromuscular coordination are *Kinesthesia* and *Proprioception*.

The Biodex Multi-Joint System allows for evaluation and training of *Kinesthesia* through:

- Limb and Joint Motion Detection Testing and Training
- Joint Motion Response Testing and Training

The Biodex Multi-Joint System allows for evaluation and training of *Proprioception* through:

- Passive Joint Reposition Testing and Training
- Active Joint Reposition Testing and Training

Only the Biodex Multi-Joint System allows the objective evaluation and challenging treatment of these essential components of function. The ability to clearly define and address them during the rehabilitation process is paramount in effectively and efficiently returning a patient to the level of function desired by the employer, or prescribed by the payor, in the shortest time possible.

<sup>1</sup>Kent E. Timm, PhD, PT, SCS, OCS, ATC, FACS

Jospt, March 1995

<sup>2</sup>The Relationship Between Subjective Knee Scores, Isokinetic Testing and Functional Testing in the ACL-Reconstructed Knee

Kevin E. Wilk, William T. Romaniello, Susan M. Soscia, Christopher A. Arrigo, James R. Andrews

Jospt, August 1994

<sup>3</sup>Abnormal Lower Limb Symmetry Determined by Function Hop Tests After Anterior Cruciate Ligament Rupture.

Frank R. Noyes, MD, Sue D. Barber, and Robert E. Mangine, MEd, LPT, ATC

The American Journal of Sports Medicine, Vol. 19, No 5

# HIGH SPEED TRAINING PRODUCES SUPERIOR RESULTS TO LOW SPEED TRAINING IN AN OLDER POPULATION

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The greatest strength decrements seem in older individuals are at high contractile speeds. Therefore this study examined the use of exercise specificity by comparing high speed (HS, n=52) versus low speed (LS, n=52) resistance training in 104 subjects ages 62-78. Subjects did three sets of nine exercises at 8-12RM, three times/week for 14 weeks. The HS group did the concentric contraction at perceived maximal velocity while the LS group took 2-3s. Both took 3-4s for the eccentric. Variables evaluated were: isokinetic torque, power and work during elbow and knee extension and flexion at 60°/s, 180°/s, and 300°/s, total dynamic constant resistance work per exercise, body composition, gait speed, agility, dynamic balance using an electronic stability platform (Biodex Inc, Shirley, N.Y.), and standup speed. Both groups made significant gains in all isokinetic variables ( $p<.001$ ), however, the HS group produced superior results for all variables at 300°/s and superior results in four of six isokinetic knee variables measured at 189°/s ( $p<.05$ ). They were also superior in dynamic constant resistance work for leg extension, leg press and seated row ( $p<.05$ ). While both groups showed significant increases in dynamic balance at the lowest difficulty level, at higher levels, which required faster adjustments, the HS group was superior ( $p<.001$ ). Neither group showed significant improvements in gait speed or body composition, however, both showed similar improvements in the agility and stand-up tests ( $p<.001$ ). These data indicate the potential for greater improvements in muscle function and dynamic balance using HS training which is specific to the decrements seen in an elderly population.

*Supported by the Miami Center on Human Factors and Aging, an Edward R. Roybal Center for Research on Applied Gerontology, Grant AG11748.*

*Excerpts from...*

## LITERATURE REVIEW: HIGH SPEED RESISTANCE TRAINING

Allen Hedricks, C.S.C.S  
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When designing resistance training programs for athletes, variables such as exercise selection, the number of sets and repetitions and frequency of training are given serious consideration. However, one variable frequently neglected is the speed of movement achieved during training...

There is evidence to suggest that the ability to generate tension at different speeds of movement is somewhat specific to the velocity at which training occurs (15,44). The principle of specificity states simply that the effects of training are specific...

"The most effective means of training may be ones that mimic the speed of performance." The use of weight lifting exercises with heavy weights at slow speed has limited merit... because this type of exercise builds big but slow muscles...

### POWER IN ATHLETICS

Power is the amount of work produced by the body per unit of time and can be calculated as the product of force and velocity. Increasing power in athletes involved in speed-strength sports enhances the opportunity for improved performance. Power is increased only if (a) the same amount of work is accomplished in a shorter period of time or, (b) an increased amount of work is accomplished in the same amount of time (49). In most athletic events, power is more important than static strength in achieving optimal performance. The importance of muscular power is also supported by Adams, Mzyhew and Moffroid who suggest that muscular power is a fundamental aspect of almost every sport. This concept was supported by Kanehisa and Miyashita (24), who said the important factor is how much power an athlete can exert, rather than how much muscular strength the athlete possesses. As suggested by Palmieri, because most sport activities are performed at high velocities, a stronger muscle is useless if it cannot produce sufficient levels of strength at the velocity required in the activity. This evidence indicates that because most athletic events involve high-speed movements, the athlete should train at speeds equal to or greater than those speeds used during competition.

### OPTIMAL STRENGTH

According to Gambetta, the critical factor is to emphasize optimum rather than maximal strength. While slow-speed strength is simply the ability to produce force, optimum (or high speed) strength improves performance.

### HIGH VELOCITY TRAINING

Numerous studies have been conducted to investigate "fast" and "slow" speeds of movement during resistance training.

In part, this interest has been stimulated by the development of isokinetic devices that permit the control of the rate of contraction. In addition, there is a widespread conviction that strength training exercises should closely simulate the athlete's specific skill(s). The majority of the investigations which studied the role of "fast" and "slow" contractions during weight training used isokinetic devices in both the training and testing of subjects. The primary reason for this is that the rate of joint movement can be predetermined by setting the isokinetic device at the desired speed.

A number of investigators have examined the role of speed of movement during isokinetic movements. There is a general consensus that those subjects who strength train at fast speeds perform better in tests at fast speeds than do subjects who train at slow speeds.

### FAST VS. SLOW

The primary area of disagreement among researchers is: Does training at fast speeds optimally improve performance at both slow and fast speeds? and Is slow training more effective than fast training at improving slow-speed strength.

Support for the superiority of high-speed training as a means of improving performance at and below training speeds was provided by Adeyanju and Moffroid and Whipple. Based on the results of their study, Moffroid and Whipple concluded that low-speed, high resistance training produces greater increases in muscular force at low speeds only. In contrast, high speed, low resistance training results in improvements in muscular force at all speeds of contraction at and below training speeds. Adeyanju came to a similar conclusion, suggesting that:

1. Isokinetic training is effective in developing low-speed strength, high speed strength and endurance.
2. Low power (low-speed, high-load) exercises produce greater increases in muscular force only at slow speeds.
3. High power (high speed, low load) exercises produce increases in muscular force at all speeds of contraction at and below the training speed.
4. Isokinetic fast-speed training is superior to slow training in the development of high-speed strength.

Mastropaolo and Takei lend further support to the superiority of high velocity training in producing increases in both slow and high speed strength. These researchers found that after training, both the slow and fast groups improved in slow strength. Additionally, the fast group improved in high speed strength and velocity (the five heaviest loads) while the slow group did not.

## **ADAPTATIONS**

It is commonly believed that strength training at low velocities recruits only slow twitch motor units, with hypertrophy occurring only in slow twitch muscle fibers. Similarly, it is believed that training at high velocity selectively recruits fast twitch fibers and causes hypertrophy of fast twitch muscle fibers.

According to Schmidtbleicher, there is clear evidence that following a high intensity strength training session there is an improvement in the ability to quickly recruit muscle fibers. It has been assumed that the cause of this adaptation is within the nervous system. In the case of trained athletes, this improvement in high speed strength is due to an improved ability to rapidly recruit motor units and increase the firing rate of motor neurons. In addition, because there is evidence that the brain organizes and initiates fast, ballistic movements differently than slow movements, many believe that neural adaptations are primarily responsible for improvements seen in the development of high-speed strength.

Neural improvements occur by increasing both the number of motor units recruited and improving the synchronization of this recruitment. Coyle et. al. has speculated that the neurological adaptations which occur as a result of high velocity training may not only include the ability to recruit more motor units during the activity, but also the synchronization with which these motor units are recruited. The improvement in synchronization is probably a result of the dendrites of the alpha motor neurons receiving increased input from the sensory fibers and the higher motor centers increasing their descending activity.

## **INTRAMUSCULAR COORDINATION**

Another mechanism by which high-speed strength is increased is improved intramuscular coordination. Intramuscular coordination, as defined by Schmidtbleicher, describes the ability of all the muscles involved in a movement to cooperate wholly with respect to the aim of the movement. Poliquin suggested that the amount of adaptation that occurs is directly related to the velocity of training. The closer a given load is moved to maximal velocity the greater the intensity of the exercise and the greater the training effect on a neuromuscular basis.

## **CONCLUSIONS**

It appears that the ability to generate high-speed strength is positively influenced during strength training when the emphasis shifts from high resistance slow-speed training to training with lower resistances and higher velocities.



*Excerpts from...*

## **ISOKINETIC TECHNOLOGY**

Scott M. Lephart, PhD, ATC  
Director, Sports Medicine and Athletic Training  
Director, Neuromuscular Research Laboratory, University of Pittsburgh

### **SCIENTIFIC BASIS, MERITS AND LIMITATIONS**

Isokinetic dynamometry has evolved considerably since its inception by Hislop and Perrine. The ability to objectively quantify and document muscular strength has given sports medicine clinicians and researchers the opportunity to greatly expand the current body of knowledge. By fixing the angular velocity of movement through accommodating resistance, isokinetic dynamometry allows isolated muscle groups to exert maximal force throughout the full range of motion. This unique feature has allowed objective comparisons between bi-lateral limbs as well as agonist to antagonist muscle groups. These measurements have resulted in the generation of various bi-lateral and reciprocal muscle group ratios among the general athletic populations. Researchers and clinicians alike have benefited from such information in regards to comparisons to individuals experiencing musculoskeletal pathology.

### **MODALITIES FOR STRENGTH ASSESSMENT AND DEVELOPMENT**

Isokinetic exercise and assessment can be considered the most objective measures for muscle group strength. Although muscle group evaluation can be measured by other modes of exercise (namely, isometric and isotonic), these methods lack the objective generation of values such as peak torque, work and power that isokinetic dynamometry provides.

### **APPLICATIONS TO SPORTS MEDICINE**

The application of isokinetic exercise to injury rehabilitation can be significant. In addition, isokinetic evaluations may be able to detect bi-lateral or reciprocal muscle group imbalances which may be related to various musculoskeletal overuse disorders in the physically active individual. The ability to identify bi-lateral or reciprocal muscle group imbalances allows isokinetics to be used as a screening device prior to the commencement of physical activity which in many cases may precede musculoskeletal pathology.

*Excerpts from...*

## **ISOKINETIC TECHNOLOGY SCIENTIFIC BASIC, MERITS AND LIMITATIONS**

Walter R. Frontera, MD, PhD  
Associate Professor and Chairman  
Department of Physical Medicine and Rehabilitation  
Harvard Medical School and Spaulding Rehabilitation Hospital  
Boston, Massachusetts, USA

### **THE CONCEPT**

Isokinetics is based on the concept that the angular velocity of a moving limb can be maintained constant by changing the force generated by a device to resist the intended movement. We should remember that the force generated by a muscle is not constant throughout the range of motion and depends on the joint angle, bony leverage, and muscle fiber length-tension considerations. During an isokinetic movement the device produces a force similar in magnitude to that produced by the muscle at every angle of the range of motion but in the opposite direction. The limitation of “isotonic” exercise training (ie, that the resistance has to be matched to the weakest point of the range of motion) is therefore overcome.

### **MEASURING MUSCLE STRENGTH**

The need to quantify muscle strength in both the research laboratory and in the clinic, cannot be overemphasized. For many years, clinicians in physical medicine and rehabilitation, orthopedics, and neurology have depended on the manual muscle test to evaluate the strength of various muscle groups as part of the physical examination of the patient. These tests, although clinically useful in some conditions, lack the sensitivity to detect minor but significant losses of muscle strength. Further, manual muscle testing is conducted under static conditions and usually at one or two joint angles. Great caution should be exercised when extrapolating these results to other joint angles and to dynamic conditions typical of everyday life activities and many athletic events.

In this regard, isokinetic devices have been shown to be a very useful technique to evaluate muscle function. From my point of view, the advantages of isokinetic devices include the ability to test various muscle groups acting on different joints, the objective nature of the results, the capacity to evaluate different physiological characteristics of the muscle such as strength and endurance, the possibility of using visual feedback to motivate the subject, and the possibility of repeating the test under similar conditions to evaluate the changes with training and/or rehabilitation.

Excerpted From:

## THE RELATIONSHIP BETWEEN SUBJECTIVE KNEE SCORES, ISOKINETIC TESTING, AND FUNCTIONAL TESTING IN THE ACL-RECONSTRUCTED KNEE

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*A positive correlation was noted between isokinetic knee extension peak torque (180, 300°/sec) and subjective knee scores, and the three hop tests. A statistical trend was noted between knee extension acceleration and deceleration range at 180 and 300°/sec for the timed hop test and triple cross-over hop.*

Isokinetic testing is a commonly utilized tool for the assessment of muscular strength in the orthopaedic and sports medicine setting. Isokinetics are frequently chosen because of their inherent patient safety, objectivity, and reproducibility in testing measures...

Limiting data analysis solely to peak torque and work parameters has stymied the development of isokinetic test data interpretation for other test parameters such as acceleration and deceleration rates during knee movements. Human movements, especially sports movements, utilize a series of accelerating and decelerating limb movements that are accomplished through concentric, eccentric, and static muscular contractions...

This complex function is accomplished through the interaction of afferent neurologic input and the ability to cause change through efferent output, which produces a muscular response. Thus, the neurophysiologic integrity of the muscle is critical in the assessment of contractile tissue, and traditional isokinetic test data interpretation (ie., peak torque) may not adequately assess normal muscular function...

Knee joint muscle testing was performed on a Biodex (Biodex Corporation, Shirley, NY) isokinetic dynamometer at velocities of 180, 300 and 450°/sec. All patients included in this study had at least two prior exposures (testings) on the Biodex to familiarize them to the machine and testing sequence...

The isokinetic testing results were analyzed utilizing Biodex 3.2 software. The peak torque repetition was determined for both the knee extensors and flexors. Then, utilizing the peak torque repetition, curve analysis was employed to determine the range of motion to reach the preset isokinetic angular velocity and the range of motion at the preset speed. Additionally, the motion required to slow the limb after reaching the preset speed was also recorded. Thus, the torque curve for the knee extensors and flexors exhibited three distinct portions (acceleration, isokinetic torque range, and deceleration)...

The acceleration of the limb was defined as the upslope of the curve and represents the arc of motion required to accelerate the limb to the preset isokinetic velocity. The deceleration phase is the downslope and represents the arc of motion required to slow the limb...

### CORRELATION BETWEEN CONCENTRIC STRENGTH AND HOP TESTS

A relationship and positive correlation existed between knee extensor peak torque at 180°/sec and the timed hop, hop for distance, and triple cross-over hop. To a lesser extent, a statistical

trend was noted for the knee extensors at 300 and 450°/sec and all three functional tests. A statistical trend was also noted for the knee acceleration range at 180°/sec and the cross-over hop test and at 300°/sec and the timed hop and the cross-over hop test...

A positive correlation was demonstrated between knee extensors peak torque at 180, 300°/sec, and the patients' subjective knee assessment scores. The positive correlation demonstrated between subjective knee assessments by the patient and the ability to generate torque rapidly during isokinetic knee extension has been noted empirically for some time. The data presented in this study illustrates a positive relationship between knee acceleration lunges at 180 and 300°/sec during isokinetic testing and the subjective knee score...

A trend was noted between the acceleration range and the functional tests, especially the cross-over hop test...

It would appear that during high-velocity (180 and 300°/sec) isokinetic exercise, there is a significant antagonist muscle contraction that appears to decelerate the limb and may effectively reduce (control) ACL stress...

Although three studies (2, 22, 82) have demonstrated no correlation between isokinetic testing and function, seven investigations (4, 45, 67, 86, 101, 102, 107) have demonstrated a positive relationship between these two parameters. Two of the studies demonstrating no functional relationship to isokinetics utilized the vertical jump as one of their functional tests, which does not correlate well to functional ability, according to Noyes et al (68). In addition, two of these three studies utilized a Kin-Com isokinetic dynamometer, which tests the knee flexors and extensors independently in two separate positions. It is the utilization of this non-reciprocal testing method that may actually provide the inability for a functional relationship in these three investigations. The remaining seven studies demonstrating a positive functional relationship with isokinetics and this investigation all utilized... systems, which test the knee extensors/flexors in a reciprocal manner. Based on the neurophysiologic information previously presented and the results of this investigation, the reciprocal testing position is crucial to the functional translation of isokinetic testing. Reciprocal testing may appear to provide normal, appropriate neuromuscular input to the lower extremity, and the adequate interpretation of isokinetic parameters that assess the neuromuscular status is imperative. The results of this investigation illustrate that traditional test measures, as well as acceleration/deceleration parameters

of isokinetic testing result in a positive relationship to functional performance...

Acceleration parameters as described in this study positively relate to both the subject's subjective knee rating and the ability of the lower limb to quickly generate peak isokinetic torque in an efficient manner. Additionally, deceleration parameters described in this study positively correlate to functional performance measures requiring controlled rotation and deceleration. The neurophysiologic information and this early study clearly demonstrate that isokinetic testing is not simply assessing the function of the agonist musculature, but also the ability of the neuromuscular system to appropriately coactivate during reciprocal motions, or the antagonistic movement.

So, from this investigation, the neurophysiologic literature, and the eight previous studies relating isokinetics to function, it appears that a positive correlation does exist among these parameters when performed reciprocally. Also, appropriate interpretation of isokinetic parameters as described in this investigation, including acceleration/deceleration and peak torque, can provide highly useful information regarding the functional capacity of the lower extremity neuromuscular system following knee injury or surgery...

The ability of an individual to generate force (ie., torque) may not be the sole critical factor. The ability to stabilize the knee joint during functional activity may be more vital. The concept of joint stability is complex. Dynamic joint stability is accomplished through the recognition of joint position, muscle coordination, and the ability to stabilize the joint as movement occurs. Thus, the patient must exhibit the ability to recognize a joint position and the skill to react to stabilize or reposition the joint. The authors refer to this concept as reactive neuromuscular control. As the patient performs these tasks consecutively and successfully, limb confidence is restored. Limb function may be restored prior to patient confidence.

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*Complete study with references available.*

EXCERPTED FROM:

## **"PRINCIPLES AND PRACTICE OF ISOKINETICS IN SPORTS MEDICINE AND REHABILITATION"**

Todd S. Ellenbecker

### **OPEN VERSUS CLOSED ISOKINETIC TESTING**

Isokinetic testing to assess lower extremity strength following ACL reconstruction has been extensively studied with isokinetic training and testing forming an integral part of many post-operative protocols...

Feiring and Ellenbecker (1995) tested 23 patients, after an average of 15-week period post-ACL reconstruction, using both a traditional OKC isokinetic knee extension/flexion movement, as well as an isokinetic CKC extension (leg press) movement. Results showed that the closed chain isokinetic peak torque and work on the injured limb was 92% to 95% of that measured in the uninjured limb. Open kinetic chain knee extension testing conducted at the same time revealed peak torque and work values of 71% to 75% of the uninjured limb. The results of this study demonstrate significant differences between open and closed chain muscle function 15 weeks after ACL reconstruction. The addition of muscular substitution and compensation made possible through the multiple, interconnecting segments in the CKC testing and training may explain the greater degree of symmetry in muscular strength in the lower extremities with the CKC testing in this study...

### **ISOKINETICS AND FUNCTIONAL PERFORMANCE**

As isokinetic technology and application improve in the future, a better understanding between muscular strength and functional performance will be developed. Several studies have found statistically significant correlations between isokinetic muscular strength testing and human performance. Feltner et al (1994) reported a decrease in rearfoot pronation following a period of 8-week of isokinetic inversion and eversion strengthening in runners. Pawlowski and Perrin (1989) found statistically significant correlations between shoulder internal and external rotation strength at 240°/s and throwing velocity in collegiate baseball pitchers. Pedegana et al (1992) found a relationship between elbow and wrist extension and throwing velocity in professional baseball pitchers. Increases in serving velocity among elite tennis players were found following a 6-week period of isokinetic training of the internal and external rotators (Mont et al 1994, Ellenbecker et al 1988). Fleck et al (1992) reported a significant relationship between shoulder extension, horizontal adduction and internal rotation, as well as elbow extension/flexion strength and ball velocity in Olympic level team handball players. Finally, Roetert et al (1996) found a significant relationship between isokinetic trunk extension/flexion strength and tennis specific medicine ball tosses in elite junior tennis players.



EXCERPTED FROM:

# CONTINUOUS-SCALE PHYSICAL FUNCTIONAL PERFORMANCE IN HEALTHY OLDER ADULTS: A VALIDATION STUDY

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Peter C. Esselman, MD  
Barbara J. deLateur, MD  
Robert S. Schwartz, MD

## OBJECTIVE:

The continuous-scale physical functional performance test (CS-PFP) is an original instrument designed to provide a comprehensive, in-depth measure of physical function that reflects abilities in several separate physical domains. It is based on a concept of physical function as the integration of physiological capacity, physical performance, and psychosocial factors.

## SETTING:

The test was administered under standard conditions in a hospital facility with a neighborhood setting. The CS-PFP consists of a battery of 15 everyday tasks, ranging from easy to demanding, that sample the physical domains of upper and lower body strength, upper body flexibility, balance and coordination, and endurance. Participants are told to work safely but at maximal effort, and physical functional performance was measured as weight, time, or distance. Scores were standardized and scaled 0 to 12. The test yields a total score and separate physical domain scores.

## DESIGN:

The CS-PFP was evaluated using 148 older adults — 78 community dwellers, 31 long-term care facility residents living independently, and 39 residents with some dependence.

## MAIN OUTCOME MEASURES:

Maximal physical performance assessment included measures of maximal oxygen consumption ( $\text{Vo}_{2\text{max}}$ ), isokinetic strength, range of motion, gait, and balance. Psychosocial factors were measured as self-defined health status using the Sickness Impact Profile (SIP), self-perceived function using the Health Survey (SF36) and Instrumental Activities of Daily Living (IADL).

## RESULTS:

IADL scores were not significantly different among the groups. Test-retest correlations ranged from .84 to .97 and inter-rater reliability from .92 to .99 for the CS-PFP total and 5 domains. Internal consistency was high (Cronbach's  $\alpha$ ,

.74 to .97). Both total and individual domain CS-PFP scores were significantly different for the three groups of study participants, increasing with higher levels of independence, supporting construct validity. CS-PFP domain scores were significantly correlated with measures of maximal physical performance ( $\text{Vo}_{2\text{max}}$ , strength, etc) and with physical but not emotional aspects of self-perceived function.

## CONCLUSIONS:

The CS-PFP is a valid, reliable measure of physical function, applicable to a wide range of functional levels. The total and physical domains may be used to evaluate, discriminate, and predict physical functional performance for both research and clinical purposes.

Physical performance tests have become popular because of research concerns that self-reported function provides insufficient information about the type of impairment and lacks sensitivity to change. Many investigators and clinicians find physical performance measures appealing because of their potential for insight into the site and severity of functional impairment, sensitivity to change, and face validity. Several new performance tests have been published in recent years.

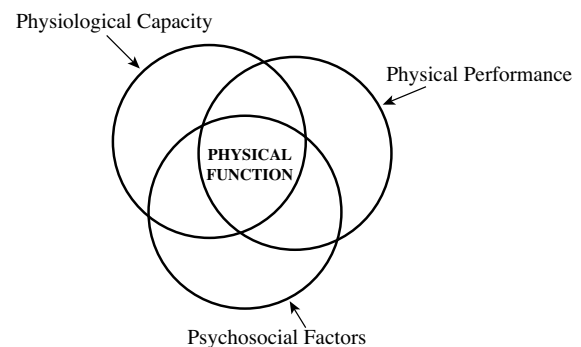


Figure 1. Venn diagram illustrating the relationships among the components of physical function.

From the Department of Medicine, Division of Gerontology & Geriatric Medicine (Dr. Cress), the Department of Rehabilitation Medicine (Drs. Questad, Esselman) and the Department of Health Services and Community Medicine (Dr. Buchner), University of Washington, Seattle; the Northwest HSR & D Field Program, Seattle Veterans Affairs Medical Center (Dr. Buchner); and the Department of Physical Medicine and Rehabilitation, Johns Hopkins University (Dr. deLateur), Baltimore, MD.

With one exception, they focus on mobility dysfunction or on people having severe limitations. Our aim was to develop a reliable measure of physical functional performance that was not constrained by ceiling or floor effects, used several physical domains and applied to a broad spectrum of abilities. A secondary goal was to develop an instrument that provides insight into causes of poor physical functional performance.

Although there is no gold standard for the measurement of physical function, several instruments are available to assess factors that contribute to physical function in varying degrees. The Venn diagram in figure 1 represents a conceptual model of the physical and psychological spheres affecting physical function. The physiological capacities of the cardiovascular, musculoskeletal, and neuromuscular systems are primary determinants of function. In this model, “physiological capacity” refers to the basic cellular and anatomic function such as cardiac ejection fraction, nerve conduction velocity, or muscle strength per cross-sectional area. “Physical performance” is the ability to integrate these physiological systems into coordinated, efficient movements to achieve optimum physical function. For example, lower extremity strength is a measure of physical performance, whereas the ability to walk upstairs represents physical functional performance. “Psychosocial factors” such as confidence, motivation, perceived ability, depressive symptomatology, and social role also influence physical function. “Physical function,” then, is the integration of physiological capacity and physical performance capability mediated by psychosocial factors. In this study, maximal physical performance measures were made under standard laboratory conditions at maximal effort. We measured strength as isokinetic torque, cardiovascular fitness as  $\text{Vo}_2\text{max}$ , and neurological function as step reaction time and balance time.

#### TIME AS A MEASURE OF STRENGTH

While time to complete a task was usually used as a measure of balance and coordination, in several tasks it is a measure of strength. Strength is dependent on the integration of muscular and neurological systems. Isokinetic performance used to measure strength is the optimal integration of the neuromuscular properties (physiological capacity) to generate force (physical performance). The potential for strength training to improve physical performance in older adults is dependent on the inverse relationship between strength (kg) and fatigue (sec). The logarithmic relationship between maximum strength and muscular endurance at submaximal tasks was first described by Simonson and later clarified. Consider a person who can lift a maximum of 20kg isotonically and hold it for 1 second. After a progressive resistance exercise program, that person can lift 40kg for 1 second and sustain a 20-kg force for 60sec. This principle also helps to clarify the relationship between strength and time. A weaker person is incapable of sustaining the contraction that allows performance in the most efficient manner. Accommodation strategies that will take longer are used to accomplish the task. For example, in the floor sweeping task, a person with weak back muscles will stand upright, using arm motion to gather litter into a pile, minimizing the time required to stoop and sweep it into the dustpan. A person with stronger back muscles will accom-

plish the task in a shorter time by stooping from the beginning and sweeping directly into the dustpan.

For the CS-PFP, tasks requiring lower back and trunk strength were classified in the lower body strength domain. For example transferring laundry, floor sweeping, vacuuming and making a bed require sustained contraction of the hip extensors throughout the duration of the task.

#### TIME AS A MEASURE OF BALANCE AND COORDINATION

For most tasks, the time required also reflected the subject's level of balance and coordination. For example, once a weight (bag, pan or basket) is lifted, the time it takes to accomplish the task is dependent on balance and coordination. Physical performance measures of the neuromuscular system (time on the wide balance beam; step reaction time) were significantly associated with time to complete tasks of the CS-PFP.

# REHABILITATION OF QUADRICEPS INHIBITED BY RUPTURE OF THE ANTERIOR CRUCIATE LIGAMENT

Gary Wilkerson

Reflex arthrogenous muscle inhibition (AMI) is the inability to activate fully the muscles acting over an injured joint. It is well established that pain-free joint effusions, whether experimentally induced, or due to acute or chronic joint pathology, prevent full voluntary activation of muscles acting across the effused joint. Hurley and Newham (*Br J Rheumatol*, 1993) have shown AMI to be present in pain-free joints without clinical effusion, following traumatic and also degenerative joint damage. They suggested that AMI is elicited by abnormal afferent information from the damaged joint, which results in decreased motor drive to muscle groups acting across the joint. They further suggested that AMI may undermine effective rehabilitation by preventing strength increases of affected muscle groups. Thus, strength losses may be partly irreversible, exposing the joint to further structural damage. If this is so, AMI may be part of the pathogenesis of degenerative joint disease.

Another study conducted by Hurley et al. (*J Orthop Rheumatol*, 1992) confirmed that quadriceps AMI in patients with ACL rupture was not reduced after rehabilitation, but it did not prevent strength increase of the inhibited muscles, particularly at high isokinetic velocities. The presence and magnitude of AMI was determined by the superimposition of electrical stimulation on an isometric maximal voluntary contraction. If a muscle is not inhibited, the electrical stimulation does not generate any additional force above that of the voluntary contraction. However, when the muscle is inhibited, additional force is generated by each electrical impulse. As the force of the voluntary contraction and the percentage inhibition are known, the true strength of the inhibited muscle can be estimated. Pre- and post-training isokinetic testing was performed at speeds of 30, 60, 90, 120 and 180 degrees per second. AMI, present isometrically and at lower isokinetic velocities, appeared to be overcome at the higher velocities, i.e. 180 degrees per second. Hurley et al. theorized that larger strength gains observed at higher velocities may be due to uninhibited "fast" dynamic contractions exerting a greater stimulus for strength gain, compared with "slower" inhibited velocities.

Our clinical observations suggest a plausible explanation for the findings of Hurley et al. Because Type II (fast twitch) motor units have a greater activation threshold than Type I (slow twitch) motor units, Type II motor units are activated with slow-speed movement only when needed for genera-

tion of maximal muscle force (e.g. 60 degrees per second isokinetic testing). If some portion of the pool of available Type II motor unit is inhibited, and therefore incapable of contributing to maximal voluntary force output, peak torque will be decreased. If AMI exerts a lesser influence at higher velocities (as suggested by Hurley et al.) peak torque deficits (involved vs. uninvolved) at high isokinetic velocities would be of lesser magnitude than those observed at slower velocities, which is consistent with our clinical observations. Although AMI may have a lesser effect on fast-speed peak torque, which is almost always generated on the first or second repetition, it may still be a factor that affects the responsiveness of the Type II motor unit pool during fast movement. We have observed that patients who demonstrate large peak torque deficits at 60 degrees per second also demonstrate rapid fatigue during the performance of a 15-repetition 300 degree per second test. We have noted that total work and average power deficits are consistently greater than peak torque deficits at 300 degrees per second. We theorize that these high-speed performance deficits are due to inhibition of some portion of the available pool of Type II motor units.

We agree with Hurley et al., who stated: "Dynamic training at higher isokinetic speeds could promote greater strength gains, since AMI appears to be less, or even absent, during faster isokinetic contractions." Increasing quadriceps performance capabilities through high-speed isokinetic training (which results from an enhanced ability to recruit a greater number of Type II motor units) may increase the responsiveness of the available pool of Type II motor units during slower movement. This concept provides the rationale for our clinical practice of testing the quadriceps at 60 and 300 degrees per second, with subsequent training at speeds of 300 or 450 degrees per second whenever isokinetic test results suggest the presence of AMI.

If further conclusive evidence is gathered to support this explanation for impaired quadriceps performance, and to confirm the benefit derived from high-speed isokinetic training, there may be a profound increase in the use of high-speed isokinetics for knee rehabilitation. As Hurley et al. stated: "Any impediment, such as AMI, that prevents normal quadriceps function and hinders effective rehabilitation of these patients, may have dire consequences for functional ability of the patient and morbidity of the joint."

# A COMPARISON OF TIBIOFEMORAL JOINT FORCES AND ELECTROMYOGRAPHIC ACTIVITY DURING OPEN AND CLOSED KINETIC CHAIN EXERCISES

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## Abstract

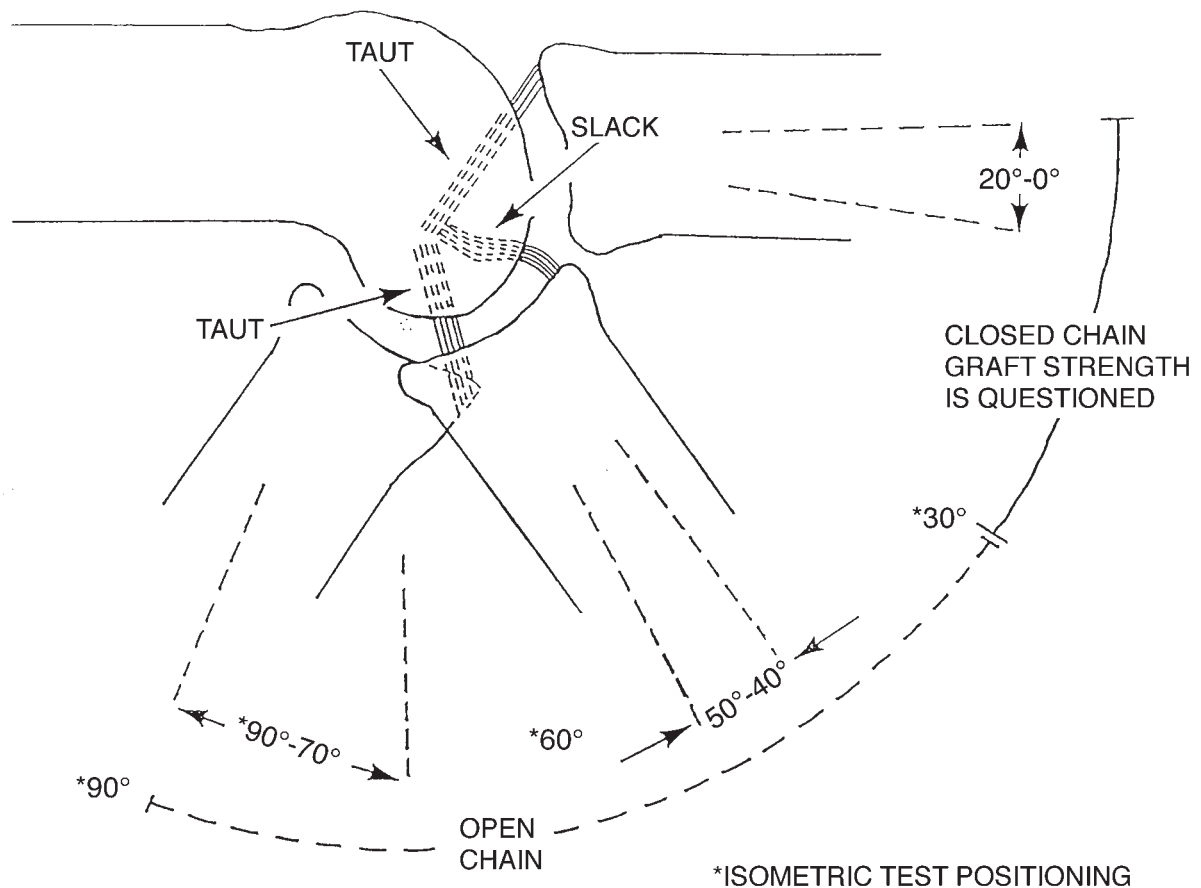
We chose to investigate tibiofemoral joint kinetics (compressive force, anteroposterior shear force, and extension torque) and electromyographic activity of the quadriceps, hamstring, and gastrocnemius muscles during open kinetic chain knee extension and closed kinetic chain leg press and squat.

## Summary of Results

Based on the results of this study, the authors conclude the following:

1. Isotonic closed kinetic chain exercise produced significantly greater compressive forces than the open kinetic chain knee extension.
2. During closed kinetic chain exercises, a posterior shear force (PCL stress) was generated throughout the entire range, with maximal shear occurring from 85° to 105° of flexion. During knee extension there is an anterior shear force (ACL stress) from 38° to 0° and posterior shear force from 40° to 101°.
3. There was greater posterior shear force produced during the closed kinetic chain exercises compared with open kinetic chain exercise.
4. Not all closed kinetic chain exercises produce a co-contraction of the hamstring and quadriceps muscles, the magnitude of the co-contraction activity depended on trunk position relative to the knee joint and the application of force and knee flexion angle.

These results are clinically relevant in that they provide the scientific rationale for the judicious use of both closed and open kinetic chain exercises when developing a rehabilitation program for the patient with an injured knee.



**".....ISOKINETIC TESTING  
IS SAFE FOR THE ACL PATIENT.  
IF GRAFT STRENGTH IS QUESTIONED,  
TESTING SHOULD BE PERFORMED  
FROM 100 TO 30° OF KNEE MOTION."**

THE EFFECTS OF PAD PLACEMENT AND ANGULAR VELOCITY  
ON TIBIAL DISPLACEMENT DURING ISOKINETIC EXERCISE

Kevin E. Wilk, PT / James R. Andrews, MD

JOSPT 17:1 January 1993



# LIGAMENTOUS KNEE INJURIES AND MUSCLE INHIBITION

D.J. Newham, M.V Hurley and D.W. Jones

## INTRODUCTION

Weakness and wasting of muscles acting over a damaged joint is a commonly observed phenomenon and has been termed arthrogenous muscle weakness (Stokes and Young, 1984). The mechanism for this weakness is not clear, but it appears to be due to muscle atrophy, rather than loss or destruction of muscle fibres (Young et al., 1982). One possible cause of the atrophy could be simple disuse, particularly if the joint is immobilized (MacDougall et al., 1980). Another cause could be a reflex inhibition, preventing full muscle activation, as has been demonstrated both in the presence (Erickson, 1982; Arvidsson et al., 1986) and absence of pain (De Andrade et al., 1965; Stokes and Young, 1984; Shakespeare et al., 1985).

In this study we have investigated the presence of muscle inhibition in the quadriceps of patients with a longstanding, painfree, ligamentous knee joint injury but without clinical effusion. Muscle inhibition and force were measured during an isometric contraction. In an attempt to gain further insight into the functional relevance of inhibition, dynamic contractions have also

been studied. Force was measured during isokinetic contractions at a number of velocities, and power output measured from a one-legged vertical jump.

## METHOD

Dynamic muscle force was measured through the unadapted dynamometer during a quadriceps contraction from 90° knee flexion to full extension. The peak force was recorded isometrically, and at velocities of 30, 60, 90, 120 and 180° s.

## RESULTS

At the highest test velocity the forces generated by the affected leg were those that would be expected if there was no inhibition, the implication being that inhibition had been overcome. The convergence of the force: velocity data for the two legs argues that inhibition has some direct relationship with force since this also decreases as velocity increases. Fast dynamic work does appear to overcome the inhibition and, if further work supports this finding, the clinical implication might be that strength training regimens would be most effective if high-velocity contractions were used.

# RESTORING MUSCLE STRENGTH WITH ISOKINETICS

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Since their inception, rehabilitation programs have focused on exercise to improve function. Improving muscular coordination and strength using specific exercises, in fact, is a main recovery component to most physical therapy pathologies. But how have isokinetic dynamometers—a group of strength devices—interfaced with rehab to promote recovery?

Technology provided an answer to resistance limitations of free weights in the late 1960s with the advent of isokinetic dynamometry. Isokinetic resistance is an accommodating force that varies while exercise speed remains constant. For the first time, muscle force could be quantified and measured more accurately, which wasn't possible using free weights. To establish lifting ability with free weights, for instance, you must experiment with different loads. An optimal return of strength may not be possible, however, because the weight remains constant through the course of an exercise. In addition, muscle fatigue contributes to the inability to accurately measure strength.

Isokinetic dynamometers perfect the repetitive lifting motion by automatically varying the resistance to coincide with the strongest part of the motion—the midway point of a leg extension, for instance—with the weakest—the beginning and finishing points. Isokinetic dynamometers measure strength levels for you. During and after the exercise bout, a machine tells patients how they've done.

The most common candidates for isokinetic dynamometers, which can be used for the spine as well as upper and lower extremities, are patients with orthopedic injuries or other neuromuscular conditions. But, in rehabilitation, strength must be secondary to protecting injured and healing tissues. Exercise safety is paramount in strength enhancement.

However, isokinetics presents a series of questions for clinicians and researchers, questions that have led to modifications of isokinetic devices. Among those inquiries are:

- Should isokinetic testing and rehabilitation be a closed or open kinetic chain?
- What exercise speeds are appropriate?
- What exercise speeds are functional?
- Does eccentric (muscle lengthening) muscle action behave like concentric (muscle shortening) muscle action? Should both be measured?

With isokinetic devices for lower extremities, closed or open chain exercises can be applied. A closed kinetic chain can be defined as a proximal segment moving relative to a fixed distal segment, comparable to squatting, where the body moves relative to a fixed foot. Closed chain exercise for lower extremities increases joint stability using compression. It

also uses multiple muscle groups and axes of motion, promoting strength throughout an entire extremity.

An open kinetic chain is just the opposite motion: the distal segment moves relative to a proximal fulcrum or axis. Open chain exercise, like the knee extension device, focuses on a specific muscle or muscle group. This isolation reduces the chance of substitution and allows an exercise to focus more specifically on the area of weakness.

Although most isokinetic devices were designed for open chain testing and muscle group isolation, the isokinetic leg press device challenges the true definition of a closed kinetic chain. In this instance, the foot is moving while the hips remain stationary. This application allows clinicians to use accommodating resistance in connection with the polyarthrodial and stabilizing nature of closed chain exercise.

Clinicians should be cognizant of the force/velocity relationship, which varies with concentric and eccentric muscle action. During concentric exercise, as the velocity of exercise increases, force production decreases. During eccentrics, increased velocity increases force production. Therapists use this force/velocity method to design exercise paradigms that decrease compressive load by increasing the concentric speed of exercise. For example, compressive disease of the patella may tolerate higher speed concentric exercise better than the low speed exercise. High speed eccentric exercise would be inappropriate.

Also, consider the carryover effect from speed-to-speed and concentric-to-eccentric strength training, and vice versa. Research has probed the effectiveness of exercise at different velocities and has questioned whether strength gains can carry over. Does an exercise performed at 30 degrees per second produce better results than at 70 degrees per second? Evidence supports that the range of carryover from one velocity to another is approximately 30 to 70 degrees per second. Also, limited research suggests that concentric training has a greater carryover to eccentric performance, rather than eccentric to concentric.

In practice, most clinicians incorporate multiple speeds of exercise (spectrum training) in increments of 30 to 50 degrees per second. Although the speed selection is arbitrary, evidence supports this approach. Also, many clinicians include eccentric training in rehab protocols for a more comprehensive approach, even if isokinetic eccentrics aren't included.

While isokinetic exercise may be the most pervasive method in rehab clinics, it is not the only high technology device available. Additional methods include computerized balance systems and devices which use variable electromagnetic resistance; and task simulators and muscle stimulators, which offer sophisticated methods to address function and

recovery. Cabled exercise machines and resistance-altering, camploading devices are also common. As this technology continues to emerge, analysis and thoughtful application is required. You must decide which methods are necessary, while considering the high costs of technology under the strains of cost controls and managed care.

However, technology has dramatically enhanced rehab's profile in the medical community. Now, more than ever, you must analyze technological applications and document outcomes to ensure your effectiveness and survival.

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# CURRENT TRENDS IN REPAIR AND REHABILITATION OF ISOLATED, COMPLETE, ACUTE ANTERIOR CRUCIATE LIGAMENT INJURIES.

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## PURPOSE

There is a continued variance in the management of an ACL injured patient. The purpose of this study was to identify current trends in the surgical and rehabilitation management of isolated, complete (acute) ACL injuries, in order to validate the effectiveness of current practices.

## SUBJECTS

Two hundred and fifty randomly selected orthopaedic surgeons were chosen from the 1993 directory of the American Academy of Orthopaedic Surgeons.

## METHODS

An eighteen-question survey was mailed to surgeons and three weeks were allowed for its return. A second mailing was sent to those who did not respond.

## ANALYSES

Sixty-seven surveys that were returned were applicable based on the percentage of acute ACL injuries evaluated by the participating surgeons. Descriptive statistics were used to analyze responses and identify common practices in repair and rehabilitation of the ACL injured knee.

## RESULTS

Greater than 51% of surgeons schedule more than one half of their acute ACL injured patients for reconstructive surgery. Patellar tendon autograft was the most common augmentation. Ninety-seven percent attempted to vascularize this graft and 67% utilized screw fixation and extra articular repair was seldom or never used by 97%. The majority of surgeons indicated they never immobilized the knee postoperatively, but they utilized continuous passive motion, electrical stimulation, quadriceps and contraction exercise, and open-chained exercise early in the postoperative period. Close-chained exercise exercises were initiated at variable times. The majority expected return of full range of motion within six weeks. Seventy-eight percent of the time functional bracing was prescribed. Meanwhile, rehabilitative bracing was used only 49% of the time.

## CONCLUSIONS

The results of this study demonstrated the variance in surgical treatment and rehabilitation of ACL injured patients. However, based on the results obtained from this survey, the majority of orthopaedic surgeons have moved in the direction of a more aggressive and accelerated approach for patients with ACL reconstruction.

EXCERPTED FROM:

# RELATIONSHIP BETWEEN ISOKINETIC STRENGTH AND DYNAMIC KNEE FUNCTION IN ACL DEFICIENT PATIENTS

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## INTRODUCTION

Some patients with anterior cruciate ligament deficient knees (ACLD) have a dynamic adaptation during walking and other activities that consist of a decreased external knee flexion moment which is sustained by net quadriceps contraction (1). As yet it is not known to what degree quadriceps strength deficits play a role in these dynamic functional adaptations. This study examined the relationship between strength and dynamic function in both an ACLD and a normal group. This study tested the hypothesis that the isokinetic quadriceps strength in ACLD patients is significantly correlated with dynamic quadriceps function (external flexion moment) during walking and more demanding activities (jogging, jog-stop, jog-cut).

## METHODOLOGY

41 ACLD patients (21M, 20F) with an average age of  $29 \pm 9$  years and average time since injury of  $22 \pm 32$  months were tested along with 27 age gender matched normal subjects ( $28 \pm 7$  years; 15m, 12F). Static measures of knee instability for the ACLD group were measured using KT1000 (15, 20 lbs and maximum manual). Isokinetic strength for all subjects was measured at 60, 180 and 240 deg/sec.

As subjects performed multiple trials of walking and jogging activities, data were collected with a three dimensional optoelectronic (GaitLink, CFTC) system and multicomponent force plate (Bertec) (2). Inverse dynamics was used to calculate the lower extremity moments. To minimize the effect of walking and jogging speed on the associated moments, a representative trial at about the same speed for each of the activities was chosen for both the ACLD and normal groups (walking  $1.2 \pm 0.2$  m/s; jogging:  $2.6 \pm 0.4$  m/s). Five of the 41 ACLD patients refused to perform some or all of the more demanding activities. All subjects were IRB approved and received informed consent.

A multivariate regression model and Pearson's correlation coefficient were used to test whether isokinetic quadriceps strength and knee instability were significantly correlated with the peak external knee flexion moment. Differences between the strength and flexion moments in the ACLD and normal groups were identified using student's *t* tests. A significance level of  $\alpha < .05$  was used throughout.

## RESULTS

The peak external flexion moment during jogging ( $p < 0.001$ ), jog-cut ( $p < 0.001$ ) in the ACLD group was both significantly less than normal (Figure 1) and was related to the significant decrease in their isokinetic quadriceps strength ( $p = 0.027$ ; ACLD  $100 \pm 58$  Nm, Normal  $135 \pm 69$  Nm). Although a significant correlation between the isokinetic quadriceps strength and peak flexion moment during all three jogging activities was found in both the ACLD ( $p < 0.001$ ) and normal group ( $p < 0.033$ ) (Figure 2), the regression lines for the ACLD group were significantly different from those of the normal group. The slopes of the lines were not significantly different but the intercepts (at the average quadriceps strength) were significantly different. The decrease in the flexion moment during walking was not as substantial as during the jogging activities. There was no correlation between the quadriceps strength and flexion moment during walking in the ACLD group.

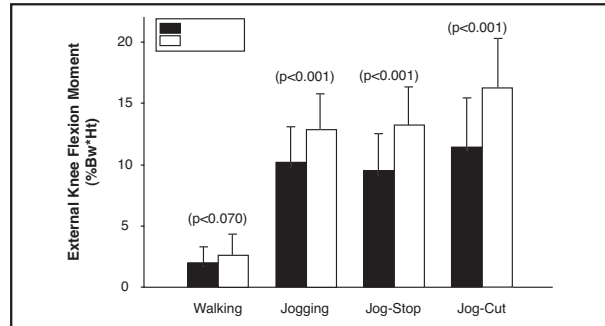


Figure 1: The external flexion moment was significantly less in the ACLD group during the more demanding activities.

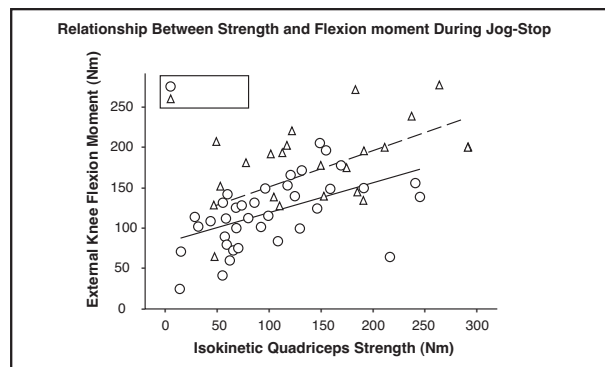


Figure 2: The isokinetic quadriceps strength and the external knee flexion was correlated.

Even though patients had unstable knees (maximum manual difference =  $7 \pm 3$  mm; 1-18 mm), there was no significant relationship between the static measures of knee instability and the external flexion moments during any of the activities ( $p < 0.280$ ).

## DISCUSSION

This study demonstrated that the isokinetic quadriceps strength was indicative of dynamic knee function during the higher demand activities in both the ACLD and normal groups while static measures of knee instability were not indicative of dynamic knee function in the ACLD group. Walking places lower demands on the quadriceps as compared to the other activities which may account for the lack of correlation between the strength deficits and the flexion moments during walking. During the jogging activities the ACLD patients had a reduced flexion moment as compared to the normals for a given strength.

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## ACKNOWLEDGEMENTS

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# CHAIN LINKS REHABILITATION PROGRAM SHOULD BALANCE OPEN AND CLOSED KINETIC CHAIN ACTIVITIES

By Gail Freidhoff, PT; ATC, George Davies, MEd., PT; ATC, and Terry Malone, EdD, PT; ATC

The best technique for rehabilitation of the lower extremity following an injury has been a long-time topic of discussion between clinicians and researchers. This is especially true in the area of sports medicine. Traditionally, rehabilitation programs have emphasized isometric or isotonic exercise regimens. With advances in technology, isokinetic strengthening has added a new dimension to the rehabilitation concept.

Open kinetic chain (OKC) movement refers to isolated joint movement during which the distal component is free to move in space with a single rotational axis that is relatively stable. Thus, one segment of the limb is stabilized while the other segment moves freely. Closed kinetic chain (CKC) movement refers to multi-joint movement around several joint axes. Multiple segments of the extremity are moving while the distal segment is fixed to a surface or object that can be moving or fixed. This is to occur in a predictable fashion.<sup>1</sup>

All segments of a limb are affected by movement occurring at one or more segments, whether using OKC or CKC or both. A moving limb segment transmits forces to all segments and, in turn, that segment is influenced by the forces generated from the other segments. In OKC activities, the muscle moves the distal attachment, while during CKC activities the muscle acts through freely moving attachments. Rehabilitation program designs should include activities that address both issues if functional activities are the final goal.

## ["A COMPLETE PROGRAM NEEDS TO INTEGRATE THE TRADITIONAL PROGRESSIVE RESISTIVE AND CLOSED CHAIN EXERCISES."]

It is vital to recognize that human movement is a combination of OKC and CKC components. Snyder-Mackler states that while weight-bearing activities have some properties of CKC, they are obviously not completely CKC.<sup>2</sup> When humans walk, 65% of the movement is CKC while 35% is OKC.<sup>3</sup> As the speed of limb movement increases, the percentage of CKC is decreased and the OKC component is increased. With running, the CKC component is 30% and the OKC component is 70%. With sprinting the difference is even more dramatic, with only 10% being CKC while 90% is OKC.<sup>3</sup> If the rehabilitation is to be comprehensive, both the CKC components and the OKC components of an activity should be considered.

In order to function safely individuals must have adequate strength and be able to employ muscles in the proper sequence to achieve smooth coordinated movements. Strength and endurance of the musculature are needed throughout the lower extremity for the safe performance of functional activities. The use of the neural pathways must be reestablished following an injury to minimize hypertrophy. During any rehabilitation, gains made during the first three to four weeks are neural adaptations in nature, while those made from weeks four to six on are related to muscle hypertrophy.<sup>4</sup> This implies that a sport-specific strength training program needs to be



*Multi-Joint System 3  
Non weight bearing open and closed kinetic chain evaluation and training.*

designed to enhance or reestablish the neural pathways necessary for optimal athletic performance. Specificity of training must be observed to ensure carryover to function. Knowing that, adaptations made in muscle recruitment patterns will differ depending on whether or not the kinetic chain is recruited or the joint is isolated. There is little if any disagreement among those directly involved in the rehabilitation of athletes that rehabilitation programs must include functional positions as well as static and dynamic positions.

Clinicians need to be mindful that modifications to rehabilitation programs must be made to ensure that the musculature around the joint is recruited in the appropriate sequence. With OKC exercises, specific joints in the kinetic chain are isolated, allowing for development of the neural pathways to specific joint musculature. These exercises are attempting to determine how well the neural system can drive the isolated musculature, prior to requiring its integrated use in the closed chain. While this does not necessarily prepare the joint for function, it does help to strengthen the specific musculature responsible for overall control of the joint so that functional activities can occur without difficulty.

With CKC exercises, the extremity is placed in a functional position, allowing the musculature optimal opportunity to be recruited in the manner in which it will be used. Although this does not guarantee that the shear forces on the joints will be eliminated, it does encourage co-contractions to occur around the joint, which should enable a protective stiffening of the functional extremity.

The popularization of CKC rehabilitation techniques is somewhat linked to work by Shelbourne and Nitz.<sup>5</sup> Although CKC



activities were emphasized in their rehabilitation program, criteria for progression to the next level were based on the results of OKC isokinetic testing at 180° and 240° per second. The results of this test were used to determine when it was permissible to progress the patient to running and jumping. One could ask, if the criteria for advancing to more challenging functional activities are based on the test results of isolated muscle contractions, should training include significant isolated contractions of the quads and hamstrings, especially since muscles respond to the SAID (specific adaptations to imposed demands) principle? Is this a valid criterion for advancement? Interestingly, it appears that this open assessment is a relatively good predictor of progression.<sup>1,6,7</sup>

There are inherent limitations and problems with both OKC and CKC activities. When only CKC rehabilitation is used, compensations in movement can occur without clear identification of the weak link in the chain. This then puts the patient at risk for other types of injury such as those occurring with overuse, and makes complete rehabilitation difficult to accomplish. When one employs only OKC activities for rehabilitation, the muscles are more or less isolated and therefore are not trained in a functional manner. This, in turn, may make it difficult for the patient to safely perform functional activities requiring coordinated CKC muscle activity. We must accept that each pattern has inherent advantages and disadvantages requiring selective application to allow optimal rehabilitation.

For a long time, clinicians have been asking the question “Which method of rehabilitation is most effective and most cost-efficient?” As early as 1981, attention was given to the type of contraction being emphasized during rehabilitation. Atha<sup>8</sup> found that strength gains were specific to the type of contraction used and that by using combinations of contraction types, larger strength gains were achieved. Since with the performance of any activity, all types of contractions occur, this is an aspect that must be considered when designing a rehabilitation program.

Research conducted by Tegner et al<sup>9</sup> in 1986, Wilkländer et al in 1987<sup>10</sup> and Sach et al<sup>11</sup> in 1989 demonstrated a positive correlation between OKC and CKC activities and function. Malone and Davies<sup>3</sup> stated that the findings of Barber et al,<sup>12</sup> Noyes et al,<sup>13</sup> and Wilk et al<sup>14</sup> further document and clarify this relationship. In 1991, however, Anderson<sup>15</sup> found no significant correlation between OKC testing and functional performance. In 1995, Davies et al<sup>16</sup> reported that the relationship of CKC testing and OKC isokinetic testing correlated with the effectiveness of CKC rehabilitation. Based on the results of the study, he concluded that it is important to include both components in a comprehensive rehabilitation program for optimal results.

Greenberger and Paterno<sup>17</sup> published an article in 1995 in the *Journal of Orthopedic Sports Physical Therapy* discussing the results of their investigation into knee extensor strength and performance on the hopping test. According to the investigators, recent literature suggests that isolated muscle testing does not provide enough information to determine functional readiness. Articles by Gray (included in his course, Chain Reaction) and Lephart (*J Ortho Sports Phys Ther*, 1992) cited by the authors suggest that isolated muscle testing does not provide enough information on functional abilities.<sup>17</sup> Mangine in 1989<sup>18</sup> and Lephart in 1992<sup>19</sup> found that training in an OKC mode only does not adequately prepare an athlete for return to full activity. All concluded that functional activity needs a more dynamic incorporation of several muscles acting together to accomplish a task.

**["ONE COULD, THEREFORE, ARGUE THAT THE RESULTS ARE SUPPORTIVE OF INCLUDING BOTH CKC AND OKC ACTIVITIES IN A REHABILITATION PROGRAM."]**

Greenberger and Paterno used the Pearson product moment correlation coefficient to compare peak torque generated by the quadriceps during isokinetic testing with distance hopped, using the one-legged hop test for each leg. Analysis of the data revealed coefficients of 0.78 for the dominant and 0.65 for the nondominant ( $p < .05$ ). Although the authors concluded that this correlation was not strong, it exceeded their level of statistical significance and was thus a significant correlation. One could, therefore, argue that the results are supportive of including both CKC and OKC activities in a rehabilitation program. Such results certainly indicate the need for continued research in this area.

**["IT IS LOGICAL TO CONCLUDE THAT FUNCTIONAL ACTIVITIES THAT INVOLVE WEIGHT BEARING ARE HELPFUL IN REDEVELOPING PROPRIOCEPTIVE FEEDBACK AND THUS DECREASE THE LIKELIHOOD OF RE-INJURY."]**

When a joint is injured, there is an alteration of joint position sense. If proprioception is not reestablished, injuries are more likely to recur. It is logical to conclude that functional activities that involve weight bearing are helpful in redeveloping proprioceptive feedback and thus decrease the likelihood of re-injury.<sup>7</sup>

In 1991, Palmitier et al<sup>20</sup> stated that while CKC is being presented to clinicians as the “best” way to exercise following an ACL reconstruction, they were unable to find conclusive evidence in the literature to support this statement. Also in 1991, Snyder-Mackler et al<sup>21</sup> evaluated ACL rehabilitation techniques and observed that quadriceps femoris strength correlates well with stance phase during walking. They concluded that alterations in gait following ACL injury and/or reconstruction were due to adaptations made as a consequence of quadriceps weakness. In 1995, Snyder-Mackler et al<sup>22</sup> looked specifically at the relationship between persistent quadriceps femoris weakness and CKC activities. Specifically, they questioned whether or not CKC activities provided adequate training stimulus to the quadriceps femoris. They concluded that CKC exercises alone do not provide enough stimulus to allow normal function of the knee during stance phase of gait early in the rehabilitation program.

Graham et al in 1993<sup>23</sup> looked at the relative stresses placed on the quadriceps femoris and hamstring muscles in varied CKC activities and found that the stresses vary greatly and that none of the CKC activities approached the training stimulus of leg extension exercises for the quadriceps femoris muscle. During the traditional quarter squat, there was only minimal activation of both the quadriceps femoris and hamstring muscles. These results concur with the work done by Snyder-Mackler. Beynnon et al<sup>24</sup> have recently published work indicating that maximizing the relationship of OKC and CKC actions on ACL graft strain is not as simple as just recommending CKC. The graft carries its greatest load in extension, in both open and closed conditions.

In the literature, much of the discussion of OKC vs. CKC exercises centers around the knee, particularly ACL injuries. Much time and consideration are devoted to the increased shear forces generated with OKC activities, which are possibly lessened during CKC exercises. It is noteworthy that the use of CKC exercises is not indicated in posterior cruciate-deficient patients, as often they are not tolerated by these individuals as the increased compressive weight-bearing/loads aggravate the existing or



*Biodex Balance System  
Weight bearing closed kinetic chain evaluation and training.*

developing osteoarthritis. CKC activities produce co-contractions of the joint agonists and antagonists, which lead to an increase in joint stability. This creates a safer exercise environment for the knee ligaments, but what about the ankle? The ankle is a multi-axial joint and CKC exercises may make the ankle condition worse early on. Therefore, one must be cautious when making blanket statements.

In a study of ballet dancers published in 1994, Irrgang et al<sup>25</sup> found that when there was a decrease in strength, there was also a decrease in the dancer's ability to perform that resulted in an increase in the potential for injury. It was concluded that this resulted from a decrease in the athlete's ability to execute appropriate ankle strategies.<sup>25</sup> While one can strengthen the plantar flexors using CKC exercises, strengthening of the invertors and evertors is more difficult using closed chain activities. Therefore, one must utilize OKC activities to strengthen this musculature.

Garn<sup>26</sup> and Glencross<sup>27</sup> found that with ankle injuries there is a decrease in the ability to detect movement. Konradson<sup>27</sup> found a decrease in the response of the peroneus longus. Although an individual may possess the ability to substitute muscular actions, this may predispose them to a higher reinjury rate. If so, when designing an ankle rehabilitation program, one must consider the inclusion of both open and closed chain activities to adequately address these two phenomena.

**[“...THERE ARE VERY FEW ACTIVITIES THAT CAN BE LABELED AS PURELY CKC OR OKC, AND THAT MOST ACTIVITIES OF THE LOWER EXTREMITIES INVOLVE BOTH OPEN AND CLOSED KINETIC CHAIN COMPONENTS.”]**

When designing a rehabilitation program for the lower extremity clinicians must be aware that there are very few activities that can be labeled as purely CKC or OKC, and that most activities of the lower extremities involve both open and closed kinetic chain components. Rehabilitation specialists need to realize that all closed chain activities are not necessarily functional and that functional activities do include some components of uniaxial, open chain activity. We must recognize the anatomical and physiological reasons for the use of CKC exercises when rehabilitating the lower extremity. Benefits derived from this form of exercise are extremely valuable for coordinated muscle action and joint receptor function. However, for a program to be complete and to give the patient optimal opportunity for a safe return to function, rehabilitation needs to integrate the traditional OKC progressive resistive exercises and the closed chain exercises.

Components of the complete program should include a balance of both OKC and CKC activities, each of which builds on the preceding skill {as indicated by the model depicted on page 59.} In doing so, clinicians can be assured that their patients will be developing all aspects of the specific skills necessary for the activities to which they wish to return.

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# HOW CAN I JUSTIFY THE CAPITAL INVESTMENT?

Financial justification is a must for all capital investments. Prudent business decisions are based on return on investments. Successful management requires growing the top line, while controlling the bottom line. In today's environment, investing in a Biodex Multi-Joint System is one of the safest and most prudent investments a manager can make. Faced with the challenge of justifying the capital investment in one fiscal year, consider the following:

## HOW MUCH REVENUE WILL THE INVESTMENT PRODUCE?

The following model is an example. Try this with your specific caseload and reimbursement schedules.

## WHERE WILL THIS REVENUE COME FROM? WILL IT PROVIDE ACCESS TO NEW MARKETS AND PATIENT POPULATIONS?

A Biodex Multi-Joint System will increase referrals and expand market opportunities. Traditional markets of orthopedics and sports medicine are well served as orthopedists continue to request Biodex tests and rehabilitation. The needs of the huge growth markets for Total Knees, Hips and Osteoarthritis are effectively addressed. Versatility to expand into the industrial medicine markets are made possible with the Biodex Multi-Joint System's Back, Lift and Work Simulation attachments.

## WILL IT REDUCE MY FULL TIME EQUIVALENTS, WITHOUT EFFECTING QUALITY OF CARE?

Yes. The efficiencies of technology will surely benefit the bottom line. Automated exercise sessions free up clinician time to work with more patients. Safe, accommodating resistance with biofeedback motivates the patient and assures compliance. Machine assisted stretching for increasing range of motion gets results while reducing the physical demands on the clinicians. Machine utilization, in association with coordinated treatment plans, optimizes assignment of clinical resources.

## WILL IT PROVIDE AN OUTCOME MEASURE FOR MANAGED CARE?

Yes. Biodex data is routinely used to objectively manage cases toward a successful outcome. Please see the associated article on 'Justifying Isokinetics for Reimbursement.'

### SAMPLE FINANCIAL MODEL

#### PATIENT CASELOAD

Average # of new patients per week requiring therapeutic exercise*	x	3
Number of weeks per year		52
Total number of new patients per year	=	156 (A)

#### THERAPEUTIC EXERCISE REVENUES GENERATED

Average # of treatment sessions per week	x	2
Average # of weeks to complete rehabilitation		8
Total number of treatment sessions per patient	=	16 (B)
Total # of treatment sessions per year (AxB)		2,496 (C)
Average reimbursement of Biodex Therapy/Exercise		\$25.00
Average co-pay for therapy visit	+	\$10.00
Total average receivables for therapy visit	=	\$35.00 (D)
Total annual Biodex Therapy/Exercise (CxD)		\$87,360 (E)

#### PHYSICAL PERFORMANCE TESTING REVENUES GENERATED

Average # of Biodex Performance Tests per patient	x	2
Average # of new patients per year (A)		156
Total # of Biodex Performance Tests per year	=	312 (F)
Average Biodex Performance Test Fee		\$30.00 (G)
Total annual Performance Revenue (FxG)		\$9,360 (H)

#### SUMMARY

Annual Biodex Therapy/Exercise Revenue (E)		\$87,360
Annual Biodex Performance Test Revenue (H)	+	\$9,360
Total annual Multi-Joint System 3 Revenue (E+H)	=	\$96,720

*\*Adding a Fall Risk Assessment and Conditioning Program to your practice will dramatically increase the volume of new patients.*

#### • THERAPEUTIC EXERCISE:

97530: Therapeutic activities, direct (one on one) patient contact by the provider (use of dynamic activities to improve functional performance), each 15 minutes.

97110: Therapeutic procedure, one or more areas, each 15 minutes; therapeutic exercise to develop strength and endurance, range of motion and flexibility.

#### • PHYSICAL PERFORMANCE

##### TEST:

97750: Physical performance test or measurement (e.g. musculoskeletal, functional capacity) with written report, each 15 minutes.

# JUSTIFYING ISOKINETICS ANSWERS TO YOUR QUESTIONS

## HOW CAN I ASSURE REIMBURSEMENT FOR ISOKINETICS?

To assure effective rehabilitation, you need to know, communicate and prove each of the following points - isokinetics gives you the answers.

1. What is the clinical status of the patient and how does it influence function?
2. What is the most appropriate treatment for the patient?
3. How much treatment will be required?
4. Has the patient been rehabilitated?
5. That there is NO less intensive or more appropriate evaluation or treatment alternative.

### ISSUE 1:

**What is the clinical status of the patient and how does it influence function?**

Disease leads to impairment, impairment leads to functional limitations and functional limitations lead to disability. Physicians, therapists and athletic trainers have relied on isokinetic testing for quantification of musculoskeletal performance impairments. The impairment is expressed as a deficit in a muscle's ability to produce force, perform work, or generate power. All the referenced studies use isokinetic assessments to establish baselines and goals for criterion based rehab programs.

### ISSUE 2:

**What is the most appropriate treatment for the patient?**

The referenced studies document treatment programs for many common pathologies. When used in conjunction with a criterion based program, the isokinetic data allows the clinician to make the appropriate changes to the clinic activity portion and/or the home based portion of the program. The isokinetic data may also show that a patient is no longer responding to therapy or that therapy should be discontinued.

### ISSUE 3:

**How much treatment will be required?**

These studies document that even with complex problems, ACLs, shoulder impingement, arthroscopic subacromial decompression, rotator cuff and ankle instability, that there are fairly consistent and predictive time frames for returning to different levels of function.

Wilk (1992) documents the status of 250 ACL reconstructed knees at 12 weeks post-op. Timm (1988) shows the results after an average of 8.9 weeks of rehab for post-surgical knees.

### ISSUE 4:

**Has the patient been rehabilitated?**

All the studies show a correlation between the rehab program, isokinetic data and return to functional activities. The study by Timm (1988) documents that isokinetic exercised based programs are more efficient and effective than non-isokinetic programs. Wilk (1991, 1992) follow-up studies with ACL patients 12 weeks and 6 months post-op document successful rehab programs. The study by Ambrosios (1994), showed the average therapy sessions for a non-surgical group was 4.39 weeks versus 7.59 weeks for the surgical intervention group. The cost of therapy was twice as much for the surgical group. Both groups achieved a high return to work rate: surgical 84%, non-surgical 98%.

### ISSUE 5:

**Is there a less intensive or more appropriate diagnostic or treatment alternative?**

No. Some consider a manual muscle test as an alternative for measuring strength. Many references to the problems associated with a manual muscle test are cited in Wilk (1991) and Kulman (1992). These problems include consistency in grading and method, subjectivity in reporting, and poor inter-tester reliability. Also, manual muscle tests are performed statically, whereas isokinetic testing renders objective reliable data regarding muscular performance during a dynamic contraction.

[“...isokinetic testing renders objective reliable data regarding muscular performance during a dynamic contraction.”] (Wilk 1991)

*The medical providers that utilize isokinetics are telling the insurance companies that they want to control costs and manage cases objectively towards a positive outcome. Insurance companies that reimburse for isokinetic tests are telling providers they expect objective case management.*

*Don't take our word, check the facts...*

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19. Ambrosios, F.M., et al: A Preliminary Comparison of Isokinetic Data Among Back Injured Surgical and Non-Surgical Patients, and the Effect of a Functional Restoration Program on their Ability to Return to Work. Iso Exer Sci 4(1), 1994.



## WHERE CAN I GET THE BEST ISOKINETIC SYSTEM?

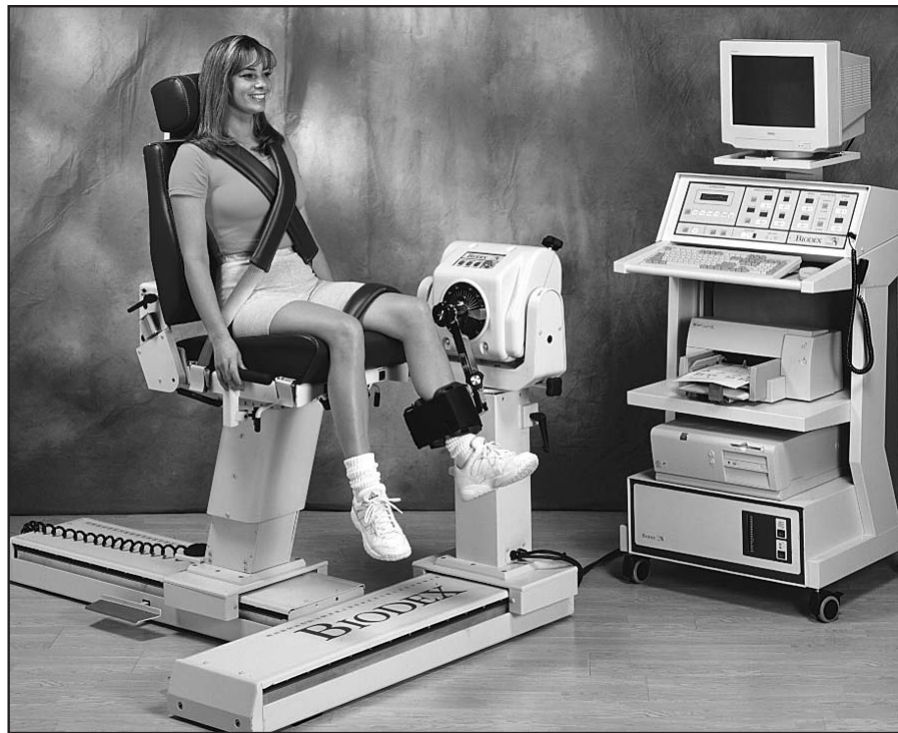
### BIODEX MULTI-JOINT SYSTEM 3 PRO, MVP AND QUICK-SET

Whether you are looking to purchase your first musculoskeletal system or upgrade and improve upon existing capabilities, the new Biodex Multi-Joint System 3 provides the versatility needed to meet a diverse caseload and the name recognition to expand your referral base to sports medicine, general orthopedic, industrial medicine, older adult, balance & mobility, pediatric orthopedics and osteoarthritis programs.

Available in three configurations, the PRO, MVP and QUICK-SET, the Multi-Joint System 3 can be used to treat patients ranging from post-op to full function. Each offers five modes for testing and exercise including Isokinetic, Passive, Isometric, Isotonic and Reactive Eccentric. Speed ranges from 0 to 500-deg./sec. with a torque of 0 to 500 ft. lbs. to provide the greatest range of any musculoskeletal system available today. New capabilities include specific modes for concentric/eccentric testing and training in isokinetic and isotonic modes.

### RETURN PATIENTS TO FUNCTION FASTER

The Biodex System 3 is sensitive to the requirements of early intervention when you must work within the healing constraints of the joints and soft tissue. Backed by the Biodex reputation for durable, high-quality clinical solutions, the Biodex Multi-Joint System 3 will empower your practice to become more efficient, more competitive and more profitable while ensuring fast, functional outcomes.



### FAST AND EASY APPLICATIONS

*What's the best piece of equipment...the one that is used the most.*

All three configurations, the PRO, MVP and QUICK-SET feature Biodex Advantage Software for Windows '95. Because System 3 makes a point of being easy to use for all skill levels, the clinical advantages of this technology is applied more often. New Touch Panel for quick, easy operation. See it. Select it. Adjust it. It's that simple. Easy-to-follow software "Wizards" guide the inexperienced user through the software while Windows '95 based applications are flexible for the advanced user. Innovative Action Video Inserts (AVIs) demonstrate patient setups, exercise and test patterns for quick memory reinforcement. Both configurations also feature a CD ROM Clinical Data Station with Pentium processor and provides real-time patient biofeedback to encourage patient compliance with exer-

cise protocols.

### CLEARLY COMMUNICATES OBJECTIVE DATA

The wide variety of printed output reports present numeric and graphic information compared to normative data for all joints, providing third party payers and referring physicians with objective information that is complete but not overwhelming. Data legends and On-screen Editing simplify the communication of test results to patient, doctor, payer or employer.

### ADVANCEMENTS

*New Isomap takes the confusion out of rehabilitation decisions.*

An Isomap is a graphic depiction and quantitative analysis of concentric and eccentric strength over a broad range of neuromuscular performance. The isomap allows the clinician to easily examine regional impairments.

By concentrating the rehabilitation program to a specific area of impairment, the clinician can dramatically speed the process of returning patients to function.

### COMMITMENT

*Biodex is your long term partner in the management of functional outcomes.*

Our commitment remains just as strong after the equipment is delivered with extensive service and support programs.

- Factory direct employed service technicians.
- Insurance company marketing and claims assistance.
- Ongoing local educational workshops.
- Continued development of clinical protocols based on new scientific information.

*Biodex becomes an active partner in the delivery of patient care...both today and tomorrow.*